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PROCEEDINGS
AND
TRANSACTIONS

OF THE
LIVERPOOL BIOLOGICAL SOCIETY.

VOL. XIII.

SESSION 1898-99.

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1899.

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PROCEEDINGS
OF THE
LIVERPOOL BIOLOGICAL SOCIETY.

OFFICE-BEARERS AND COUNCIL.

Ex-Presidents :

- 1886—87 PROF. W. MITCHELL BANKS, M.D., F.R.C.S.
1887—88 J. J. DRYSDALE, M.D.
1888—89 PROF. W. A. HERDMAN, D.Sc., F.R.S.E.
1889—90 PROF. W. A. HERDMAN, D.Sc., F.R.S.E.
1890—91 T. J. MOORE, C.M.Z.S.
1891—92 T. J. MOORE, C.M.Z.S., A.L.S.
1892—93 ALFRED O. WALKER, J.P., F.L.S.
1893—94 JOHN NEWTON, M.R.C.S.
1894—95 PROF. F. GOTCH, M.A., F.R.S.
1895—96 PROF. R. J. HARVEY GIBSON, M.A.
1896—97 HENRY O. FORBES, LL.D., F.Z.S.
1897—98 ISAAC C. THOMPSON, F.L.S., F.R.M.S.
-

SESSION XIII., 1898-99.

President :

PROF. C. S. SHERRINGTON, M.D., F.R.S.

Vice-Presidents :

PROF. W. A. HERDMAN, D.Sc., F.R.S.
ISAAC C. THOMPSON, F.L.S., F.R.M.S.

Hon. Treasurer :

T. C. RYLEY.

Hon. Librarian :

JAMES JOHNSTONE.

Hon. Secretary :

JOSEPH A. CLUBB, M.Sc., (VICT.).

Council :

H. C. BEASLEY.

W. J. HALLS.

JOSEPH LOMAS, F.G.S.

CHAS. E. JONES, B.Sc.

REV. L. de B. KLEIN, D.Sc.

REV. T. S. LEA, M.A.

G. H. MORTON, F.G.S.

JOHN NEWTON, M.R.C.S.

PROF. PATERSON, M.D.

C. RICKETTS, M.D.

W. E. SHARP.

A. O. WALKER, F.L.S.

REPORT of the COUNCIL.

DURING the Session 1898-99 there have been seven ordinary meetings and two field meetings of the Society. The latter were held at Hilbre Island, jointly with the Liverpool Geological Society and at Delamere Forest, Cheshire, respectively. In response to an invitation from the Owens College Biological Society, several of our members attended one of the meetings at Manchester to hear an illustrated address by Dr. Arthur Willey, entitled "In search of Nautilus," which embodied a description of his recent travels in the Pacific.

The communications made to the Society have been representative of almost all branches of Biology and the exhibition of microscopic preparations and other objects of interest has been well maintained at the meetings.

On the occasion of a lecture entitled "Malaria and Mosquitos," given before the Society by Major Ross, I.M.S., lecturer on Tropical Diseases at University College, your Council adopted the plan of issuing special invitations for the meeting, and the large and influential audience which assembled testified both to the interest and the value of the new departure.

The Library continues to make satisfactory progress, and additional important exchanges have been arranged during the year. The Hon. Librarian has in contemplation the preparation of a detailed catalogue which will be of great use to members.

The Treasurer's statement and balance sheet are appended.

No alterations have been made in the Laws of the Society during the past session.

The members at present on the roll are as follows :—

Honorary Members 9

Ordinary Members 57

Student Members 16

—
Total..... 82

SUMMARY of PROCEEDINGS at the MEETINGS.

The first meeting of the thirteenth session was held at University College on Friday, October 14th, 1898.

1. The following exhibits were on view in the Zoological Laboratory from 7 to 7-30.

A series of photographs, illustrating animal and plant life between tide marks, was shown by Prof. Herdman.

A number of mounted preparations from the Fisheries Museum, by Mr. J. Johnstone.

The President-elect (Prof. C. S. Sherrington, M.D., F.R.S.) took the chair at 7-30, in the Zoology Theatre.

2. The Report of the Council on the Session 1897-98 (see "Proceedings," Vol. XII., p. viii.) was submitted and adopted.
3. The Treasurer's Balance Sheet for the Session 1897-98 (see "Proceedings," Vol. XII., p. xxxiii.) was submitted and approved.
4. The Librarian's Report (see "Proceedings," Vol. XII., p. xxv.) was submitted and approved.
5. The following Office-bearers and Council for the ensuing Session were elected :— Vice-Presidents, Prof. Herdman, D.Sc., F.R.S., and I. C. Thompson, F.L.S., F.R.M.S; Hon. Treasurer, T. C. Ryley; Hon. Librarian, James Johnstone; Hon. Secretary, Joseph A. Clubb, M.Sc.; Council, H. C. Beasley, W. J. Halls, Chas. E. Jones, B.Sc., Rev. L. de Beaumont Klein, D.Sc., Rev. T. S. Lea, M.A.,

Joseph Lomas, F.G.S., G. H. Morton, F.G.S., John Newton, M.R.C.S., Prof. Paterson, M.D., M.R.C.S., C. Rickets, M.D., W. E. Sharp, A. O. Walker, F.L.S.

- 6, Prof. Herdman submitted the Twelfth Annual Report on the work of the Liverpool Marine Biology Committee and the Port Erin Biological Station (see "Transactions," p. 21).
7. Mr. A. R. Jackson, B.Sc., gave a short note on his work on the Spiders found in the neighbourhood of Port Erin (see "Transactions," p. 66).

The second meeting of the thirteenth session was held at University College on Friday, November 11th, 1898. The President in the chair.

1. Prof. Sherrington, M.D., F.R.S., delivered the Presidential address, entitled "Adaptation to Function as exemplified by the Structure of the Arm" (see "Transactions," p. 1). A vote of thanks was proposed by Dr. Wigglesworth, seconded by Prof. Boyce and carried with acclamation.

The third meeting of the thirteenth session was held at University College on Friday, December 9th, 1898. and took the form of a joint meeting with the Liverpool Geological Society and the Historic Society of Lancashire and Cheshire. The President in the chair.

1. In the Zoological Museum of the College Prof. Herdman exhibited a series of Anthropological specimens and Prof. Paterson described a series of exhibits, prepared by Dr. Lovegrove and himself, illustrating peculiarities in the vertebral column of the human foetus.

2. Mr. J. Lomas, F.G.S., delivered a lecture on "Recent Finds of Flints in Cheshire and North Wales, and their bearing on the Antiquity of Man." A number of the specimens found were exhibited and the opinions of eminent experts were quoted to show that these flints owed their shape to human rather than natural agencies. The lecture was also illustrated by photographs and lantern slides. An animated discussion followed.
-

The fourth meeting of the thirteenth session was held at University College on Friday, January 13th, 1899. Prof. Herdman (Vice-President) in the chair.

1. In the Zoological Laboratory Prof. Herdman exhibited a series of microscopical preparations of the radulæ of molluscs, and Dr. Wiglesworth exhibited and made some remarks upon the eggs of the Roseate Tern (*Sterna dougalli*).
 2. A paper on "Aerial Roots of the Ivy," by Prof. Harvey Gibson, was communicated by Prof. Herdman (see "Transactions," p. 185).
 3. Mr. W. E. Sharp communicated a paper on "Some Speculations on the Derivation of our British Coleoptera" (see "Transactions," p. 163).
-

The fifth meeting of the thirteenth session was held at University College on Friday, February 10th, 1899. The President in the Chair.

1. From 7 to 7-30 in the Physiological Laboratory a series of miscellaneous exhibits were on view, and Dr. Grünbaum described an apparatus for measuring the vitiation of the air in a room.

2. Prof. Paul gave a lecture entitled "Contributions to the Histological Study of Dentine." With the aid of a series of lantern slides produced from microphotographs the development of dentine was graphically traced. Many of the slides from which the illustrations were prepared were on view under microscopes, and were inspected with great interest at the close of the lecture.
-

The sixth meeting of the thirteenth session was held at University College on Friday, March 17th, 1899. The President in the chair.

1. Mr. J. Johnstone exhibited with remarks a series of microscopic preparations illustrating Spawn formation in the Marine Mussel.
 2. The Annual Report of the Sea-Fisheries Laboratory for 1898 by Prof. Herdman, A. Scott, and J. Johnstone was submitted (see "Transactions," p. 69).
 3. Mr. I. C. Thompson submitted some notes comparing the results of Deep-Sea and surface Tow-Nettings in the Irish Sea (see "Transactions," p. 156).
 4. Prof. Paterson gave a lecture on "Perforations in the Parietal Bones, including an account of a microcephalic cranium from the Liverpool Museum." An interesting series of photographs were shown of the skulls with such perforations in illustration of the lecture.
-

The seventh meeting of the thirteenth session was held at University College on Friday, May 12th, 1899. The President in the chair.

1. A series of miscellaneous exhibits were on view previous to the meeting.
 2. Major Ross, I.M.S., gave a lecture on "Malaria and Mosquitos," in which he showed the important part played by mosquitos in the spread of malaria. A beautiful series of microscopic sections illustrated the lecture, which was listened to with great interest by a large audience.
-

The eighth meeting of the thirteenth session was held as a Field Meeting, jointly with the Liverpool Geological Society, on Saturday, June 10th, 1899, at Hilbre Island and West Kirby.

The ninth meeting was held, also as a Field Meeting, at Delamere Forest, Cheshire, on Saturday, June 17th. After tea a short business meeting was held. On the motion of Prof. Sherrington, seconded by Mr. Ryley, Dr. Wigglesworth was unanimously elected President for next session. On the motion of Prof. Herdman, seconded by Mr. Beasley, a vote of thanks was passed, with acclamation, to Prof. Sherrington the retiring President.

LAWS of the LIVERPOOL BIOLOGICAL SOCIETY.

I.—The name of the Society shall be the “LIVERPOOL BIOLOGICAL SOCIETY,” and its object the advancement of Biological Science.

II.—The Ordinary Meetings of the Society shall be held at University College, at Seven o'clock, during the six Winter months, on the second Friday evening in every month, or at such other place or time as the Council may appoint.

III.—The business of the Society shall be conducted by a President, two Vice-Presidents, a Treasurer, a Secretary, a Librarian, and twelve other Members, who shall form a Council; four to constitute a quorum.

IV.—The President, Vice-Presidents, Treasurer, Secretary, Librarian, and Council shall be elected annually, by ballot, in the manner hereinafter mentioned.

V.—The President shall be elected by the Council (subject to the approval of the Society) at the last Meeting of the Session, and take office at the ensuing Annual Meeting.

VI.—The mode of election of the Vice-Presidents, Treasurer, Secretary, Librarian, and Council shall be in the form and manner following:—It shall be the duty of the retiring Council at their final meeting to suggest the names of Members to fill the offices of Vice-Presidents, Treasurer, Secretary, Librarian, and of four Members who were not

on the last Council to be on the Council for the ensuing session, and formally to submit to the Society, for election at the Annual Meeting, the names so suggested. The Secretary shall make out and send to each Member of the Society, with the circular convening the Annual Meeting, a printed list of the retiring Council, stating the date of the election of each Member, and the number of his attendances at the Council Meetings during the past session; and another containing the names of the Members suggested for election, by which lists, and no others, the votes shall be taken. It shall, however, be open to any Member to substitute any other names in place of those upon the lists, sufficient space being left for that purpose. Should any list when delivered to the President contain other than the proper number of names, that list and the votes thereby given shall be absolutely void. Every list must be handed in personally by the Member at the time of voting. Vacancies occurring otherwise than by regular annual retirement shall be filled by the Council.

VII.—Every Candidate for Membership shall be proposed by three or more Members, one of the proposers from personal knowledge. The nomination shall be read from the Chair at any Ordinary Meeting, and the Candidate therein recommended shall be balloted for at the succeeding Ordinary Meeting. Ten black balls shall exclude.

VIII.—When a person has been elected a Member, the Secretary shall inform him thereof, by letter, and shall at the same time forward him a copy of the Laws of the Society.

IX.—Every person so elected shall within one calendar month after the date of such election pay an Entrance Fee of Half a Guinea and an Annual Subscription of One

Guinea (except in the case of Student Members) ; but the Council shall have the power, in exceptional cases, of extending the period for such payment. No Entrance Fee shall be paid on re-election by any Member who has paid such fee.

X.—The Subscription (except in the case of Student Members) shall be One Guinea per annum, payable in advance, on the day of the Annual Meeting in October.

XI.—Members may compound for their Annual Subscription by a single payment of Ten Guineas.

XII.—There shall also be a class of Student Members, paying an Entrance Fee of Two Shillings and Sixpence, and a Subscription of Five Shillings per annum.

XIII.—All nominations of Student Members shall be passed by the Council previous to nomination at an Ordinary Meeting. When elected, Student Members shall be entitled to all privileges of Ordinary Members, except that they shall not receive the publications of the Society nor vote at the Meetings, nor serve on the Council.

XIV.—Resignation of Membership shall be signified *in writing* to the Secretary, but the Member so resigning shall be liable for the payment of his Annual Subscription, and all arrears up to date of his resignation.

XV.—The Annual Meeting shall be held on the second Friday in October, or such other convenient day in the month as the Council may appoint, when a Report of the Council on the affairs of the Society, and a Balance Sheet duly signed by the Auditors previously appointed by the Council, shall be read.

XVI.—Any person (not resident within ten miles of Liverpool) eminent in Biological Science, or who may have rendered valuable services to the Society, shall be eligible

as an Honorary Member; but the number of such Members shall not exceed fifteen at any one time.

XVII.—Captains of vessels and others contributing objects of interest shall be admissible as Associates for a period of three years, subject to re-election at the end of that time.

XVIII.—Such Honorary Members and Associates shall be nominated by the Council, elected by a majority at an Ordinary Meeting, and have the privilege of attending and taking part in the Meetings of the Society, but not voting.

XIX.—Should there appear cause in the opinion of the Council for the expulsion from the Society of any Member, a Special General Meeting of the Society shall be called by the Council for that purpose; and if two-thirds of those voting agree that such Member be expelled, the Chairman shall declare this decision, and the name of such Member shall be erased from the books.

XX.—Every Member shall have the privilege of introducing one visitor at each Ordinary Meeting. The same person shall not be admissible more than twice during the same session.

XXI.—Notices of all Ordinary or Special Meetings shall be issued to each Member by the Secretary, at least three days before such Meeting.

XXII.—The President, Council, or any ten Members can convene a Special General Meeting, to be called within fourteen days, by giving notice in writing to the Secretary, and stating the object of the desired Meeting. The circular convening the Meeting must state the purpose thereof.

XXIII.—Votes in all elections shall be taken by ballot, and in other cases by show of hands, unless a ballot be first demanded.

XXIV.—No alteration shall be made in these Laws, except at an Annual Meeting, or a Special Meeting called for that purpose; and notice in writing of any proposed alteration shall be given to the Council, and read at the Ordinary Meeting, at least a month previous to the meeting at which such alteration is to be considered, and the proposed alteration shall also be printed in the circular convening such meeting; but the Council shall have the power of enacting such Bye-Laws as may be deemed necessary, which Bye-Laws shall have the full power of Laws until the ensuing Annual Meeting, or a Special Meeting convened for their consideration.

BYE-LAWS.

1. Student Members of the Society may be admitted as Ordinary Members without re-election upon payment of the Ordinary Member's Subscription; and they shall be exempt from the Ordinary Member's entrance fee.

2. University College Students may be admitted as Student Members of the Society for the period of their college residence, on the single payment of a fee of Five Shillings and an entrance fee of Two Shillings and Sixpence.

LIST of MEMBERS of the LIVERPOOL
BIOLOGICAL SOCIETY.

SESSION 1898-99.

A. ORDINARY MEMBERS.

(Life Members are marked with an asterisk.)

ELECTED.

- 1898 Armour, Dr. T. R. W., University College,
Liverpool
- 1886 Banks, Prof. W. Mitchell, M.D., F.R.C.S., 28,
Rodney-street
- 1886 Barron, Prof. Alexander, M.B., M.R.C.S., 34,
Rodney-street
- 1888 Beasley, Henry C., Prince Alfred-road, Wavertree
- 1894 Boyce, Prof. University College, Liverpool
- 1889 Brown, Prof. J. Campbell, 8, Abercromby-square
- 1886 Caton, R., M.D., F.R.C.P., Lea Hall, Gateacre
- 1886 Clubb, J. A., M.Sc., HON. SECRETARY, Free
Public Museums, Liverpool
- 1897 Dutton, Dr. J. Everett, 502, New Chester-road,
Rock Ferry
- 1894 Forbes, H. O., LL.D., F.Z.S., Free Public
Museums, Liverpool
- 1891 Garstang, W., M.A., Lincoln College, Oxford
- 1886 Glynn, Prof. T. R., M.D., F.R.C.P., 62, Rodney-
street
- 1886 Gibson, Prof. R. J. Harvey, M.A., F.L.S., Univer-
sity College
- 1898 Grünbaum, Dr. A. S., 67, Rodney Street
- 1886 Halls, W. J., 35, Lord-street
- 1896 Haydon, W. H., 24, Upper Parliament-street

- 1886 Herdman, Prof. W. A., D.Sc., F.R.S., VICE-PRESIDENT, University College
1893 Herdman, Mrs., B.Sc., Croxteth Lodge, Ullet-road, Liverpool
1891 Hicks, J. Sibley, M.D., 2, Erskine-street
1894 Hickson, Prof. S. J., F.R.S., Owens College, Manchester
1897 Holt, Alfred, Crofton, Aigburth
1898 Johnstone, James, HON. LIBRARIAN, Fisheries Laboratory, University College, Liverpool
1886 Jones, Charles W., Field House, Prince Alfred-road, Wavertree
1894 Jones, Charles Elpie, B.Sc., Prenton-road, W., Birkenhead
1895 Klein, Rev. L. de Beaumont, D.Sc., F.L.S., 6, Devonshire-road
1894 Lea, Rev. T. S., St. Ambrose Vicarage, Widnes
1896 Laverock, W. S., M.A., B.Sc., Free Museums, Liverpool
1886 Lomas, J., Assoc. N.S.S., F.G.S., 16, Mellor-road, Birkenhead
1888 Melly, W. R., Ph.D., 90, Chatham-street
1886 Morton, G. H., F.G.S., 209, Edge-lane, E.
1888 Newton, John, M.R.C.S., 44, Rodney-street
1894 Paterson, Prof., M.D., M.R.C.S., University College, Liverpool
1894 Paul, Prof. F. T., Rodney-street, Liverpool
1892 Phillips, E., L.D.S., M.R.C.S., 33, Rodney-street
1896 Picton, W. H., 2, College-road, Gt. Crosby
1886 *Poole, Sir James, J.P., Abercromby-square
1897 Quayle, Alfred, 7, Scarisbrick New-road, S'port
1890 *Rathbone, Miss May, Backwood, Neston
1895 Ricketts, C., M.D., 11, Hamilton-square, B'head

- 1887 Robertson, Helenus R., Springhill, Church-road,
Wavertree
- 1897 Robinson, H. C., Holmfield, Aigburth
- 1887 Ryley, Thomas C., HON. TREASURER, 10, Waver-
ley-road
- 1894 Scott, Andrew, Piel, Barrow-in-Furness
- 1895 Sherrington, Prof., M.D., F.R.S., PRESIDENT,
University College, Liverpool
- 1891 Sharp, W. E., The Woodlands, Ledsham
- 1886 Smith, Andrew T., Jun., 5, Hargreaves-rd., Sefton
Park
- 1895 Smith, J., F.L.S., Rose Villa, Lachford, Warrington
- 1898 Suffield, Miss, University College, Liverpool
- 1893 Tate, Francis, F.C.S., 9, Hackins Hey, Liverpool
- 1886 Thompson, Isaac C., F.L.S., F.R.M.S., VICE-
PRESIDENT, 53, Croxteth-road
- 1889 Thornely, Miss L. R., Baycliff, Woolton Hill
- 1888 Toll, J. M., 49, Newsham-drive, Liverpool
- 1886 Walker, Alfred O., J.P., F.L.S., Colwyn Bay
- 1897 Warrington, Dr. W. B., 80, Rodney-street
- 1891 Wiglesworth, J., M.D., County Asylum, Rainhill
- 1896 Woods, Joseph A., L.D.S. Eng., 76, Mount-
pleasant, Liverpool
- 1896 Wilmer, Miss J. H., 20, Lorne-rd., Orton, B'head

B. STUDENT MEMBERS.

- Armstrong, Miss A., 26, Trinity-road, Bootle
- Bennette, Horace W. P., Gothic Lodge, Park-road, S.,
Birkenhead
- Carstairs, Miss, Lily-road, Fairfield
- Crompton, Miss C. A., University College, Liverpool
- Dickinson, T., 3, Clark-street, Princes Park
- Drinkwater, E. H., Rydal Mount, Marlboro'-road, Tue-
brook

Elder, D., 49, Richmond Park, Liverpool
Gill, E. S. H., Shaftsbury House, Formby
Hannah, J. H. W., 55, Avondale-road, Sefton Park
Harrison, Oulton, Denehurst, Victoria Park, Wavertree
Henderson, W. S., B.Sc., Beech-hill, Fairfield
Knott, Henry, 46, Underley-street, Liverpool
Lloyd, J. T., 43, Ullet-road, Sefton Park
Mann, J. C., University College, Liverpool
Mawby, W., Clumber, Prenton-road, E, Birkenhead
Woolfenden, H. F., 6, Grosvenor-road, Birkdale

C. HONORARY MEMBERS.

H.S.H. Albert I., Prince of Monaco, 25, Faubourg St.
Honoré, Paris
Bornet, Dr. Edouard, Quai de la Tournelle 27, Paris
Claus, Prof. Carl, University, Vienna
Fritsch, Prof. Anton, Museum, Prague, Bohemia
Giard, Prof. Alfred, Sorbonne, Paris
Haeckel, Prof. Dr. E., University, Jena
Hanitsch, R., Ph.D., Raffles Museum, Singapore
Leicester, Alfred, Buckhurst Farm, nr. Edenbridge, Kent
Sohns-Laubach, Prof- Dr., Botan. Instit., Strassburg

REPORT of the LIBRARIAN.

DURING the last session of the Society, retrospective exchanges, including most of the former volumes of the Transactions, were arranged with the Kansas University (U.S.A.) and the Illinois (U.S.A.) State Laboratory of Natural History.

Attention was directed in last year's Report to the large proportion of journals and other publications in the Society's Library which still remain unbound, and which has been largely increased by last year's additions. Until this is done the arrangement and cataloguing of the Library is not convenient nor indeed practicable.

Lists are given below of the publications which have been added, by exchange and otherwise, to the Library since the end of the Twelfth Session, and of the Societies and Institutions with whom publications are exchanged.

1. Batavia, *Naturkundig Tijdschrift v. Nederlandsch-Indië*. Deel LVII., Tiende Serie, Deel I. 1898.
2. Boston, (U.S.A.) *Proceedings of the Boston Society of Natural History*, Vol. 28, pp. 117—300, December, 1897—July, 1898.
3. Bonn, *Sitzungsberichte d. Niederrheinischen Ges. f. Natur- und Heilkunde*. Erste und Zweite Hälfte. 1898.
4. Bonn, *Verhandl. d. Naturhist. Vereins d. Preussisch. Rheinlande*. Fünf. Jahr. Erste u. Zweite Hälfte. 1898.
5. Bologna, *Memorie d. R. Accademia d. Scienze dell' Istituto di Bologna*. Serie V. — T. VI. Sezione. di Scienze Naturali. Sezione di Medicina e Chirurgia. 1896-97.
6. Bordeaux, *Procès-verbaux de la Société Linnéenne de Bordeaux*. Vol. LII. 1897.
7. Bergen, *Bergens Museums Aarbog for 1898*. 1899.
8. Bergen, *An account of the Crustacea of Norway*. Vol. II., Isopoda, pts. 9—10, Munropsidae. (concluded) Ligiidae, Trichoniseidae, Oniseidae (part). G. O. Sars. 1898.

9. Berlin, Sitzungsberichte der königlich Preussischen Akademie der Wissenschaften. I.—LIV., 1898.
Bristol, Publications of the British Association, Bristol Meeting, 1898.
(Presented by Prof. Herdman.)
10. The President's Address.
11. Address to the Zoological Section by Prof. W. F. R. Weldon, F.R.S.
12. Address to the Botanical Section by Prof. F. O. Bower, F.R.S.
13. Life Conditions of the Oyster, 3rd Report of the Committee, by Prof. Herdman, Prof. Boyce, and Dr. Kohn.
14. Preliminary Note on the Migrations of the Mackerel. W. Garstang, M.A.
15. Buenos Aires, Comunicaciones del Museo Nacional de Buenos Aires. Tomo 1, No. 1, 2. 1898.
16. Brussels, Annales du Musée du Congo. Serie I.—Botanique; Tome. I. Fasc. 1 and 2. Illustrations de la Flora du Congo. Em. de Wildeman et Th. Surand. 1898.
Serie II., Zoologie, Tome I., Fasc. 2. Matériaux pour la Faune du Congo. Poissons Nouveaux. G. A. Boulenger. 1898. (Presented by the Secretary of State, Congo Free State.)
17. Cambridge, Mass., U.S.A., Bulletin of the Museum of Comparative Zoology at Harvard College. Vol. XXXII., Nos. 1—9; Vol. XXVIII., Nos. 4—5. (Geological Series Vol. III.).
18. Cambridge, Mass., U.S.A., Annual Report of the Curator of the Museum, Comparative Zoology at Harvard. 1897—98.
19. Charlottenburg, Zeitschrift für Fischeri u. deren Hilfswissenschaften mit einschluss v. Fischwasser-Hygiene, Fischerei u. Wasserrecht. Heft 1—5, 1898.
20. Charlottenburg, Mitglieder - Liste des Deutschen Fischerei - Vereins. October 1, 1898.
21. Copenhagen, Beretning fra Kommissionen f. Vidensk. Undersogelse af de Danske Farvande. Andet. Bind. Forste. v. And. Heft. 1897-99.
22. Copenhagen, Oversigt over det Kongelige Danske Videnskabernes Selskabs Forhandlinger. Nos. 1—6, 1898-99.
23. Copenhagen, Videnskabelige Meddelelser fra den Naturhistoriske Forening i Kjobenhavn f. Aaret. 1898.
24. Christiania, Forhandlinger i Videnskabs-Selskabet i Christiania. Aar 1897-98.
25. Dublin, Scientific Proc. Roy. Dublin Soc. Vol. VIII. (N.S.). November, 1898, pt. 6.
26. Dublin, The Scientific Trans. Roy. Dublin Soc. Vol. V. (Ser. II.)—XIV.—XVI.; Vol. VI., I.

27. Edinburgh, Proceedings of the Royal Society of Edinburgh. Vol. XXI., Sessions 1895-96, 1866-97.
28. Edinburgh, Sixteenth An. Report of the Fishery Board for Scotland, 1897. Pt. 3. Scientific Investigations.
29. Edinburgh, Report of Investigations on the Life History of the Salmon. Fishery Bd. for Scotland.
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- AMSTERDAM—Koninklijke Akademie van Wetenschappen
Koninklijke Zoölogisch Genootschap Natura Artis Magistra
- BALTIMORE—Johns Hopkins University
- BATAVIA—Koninklijke Natuurkundig Vereeniging in Ned. Indie.
- BERGEN—Museum
- BERLIN—Konigl. Akademie der Wissenschaften
Deutscher Fischerei-Vereins
- BIRMINGHAM—Philosophical Society
- BOLONGA—Accademia della Scienze
- BOXX—Naturhistorischer Verein des Preussischen Rheinlande und Westfalens
- BORDEAUX—Société Linnéenne
- BOSTON—Society of Natural History
- BRUSSELS—Académie Royal des Sciences, etc., de Belgique
- BUENOS AIRES—Museo Nacional
Museo de la Plata
- CAMBRIDGE—Morphological Laboratories
- CAMBRIDGE, MASS.—Museum of Comparative Zoology of Harvard College
- CHRISTIANIA—Videnskabs-Selskabet
- DUBLIN—Royal Dublin Society
- EDINBURGH—Royal Society
Royal Physical Society
Royal College of Physicians
Fishery Board for Scotland
- FRANKFURT—Senckenbergische Naturforschende Gesellschaft
- FREIBURG—Naturforschende Gesellschaft
- GENEVE—Société de Physique et d'Histoire Naturelle
- GIESSEN—Oberhessische Gesellschaft für Natur und Heilkunde
- GLASGOW—Natural History Society
- GOTTINGEN—Konigl. Gesellschaft der Wissenschaften
- HALIFAX—Nova Scotian Institute of Natural Science

HARLEM—Musée Teyler

Société Hollandaise des Sciences

HELGOLAND—Königliche Biologische Anstalt

*ILLINOIS, U.S.A.—Reports of the State Laboratory of Natural History.

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KJØBENHAVN—Naturhistoriske Forening

Danish Biological Station (C. G. John Petersen)

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LEEDS—Yorkshire Naturalists' Union

LEIPZIG—Konigl. Sachs. Gesellschaft der Wissenschaften

LILLE—Revue Biologique du Nord de la France

LIVERPOOL—Geological Society

Bulletin of the Liverpool Museum

LONDON—Royal Microscopical Society

British Museum (Natural History Department).

MANCHESTER—Microscopical Society

Owens College

MARSEILLES—Station Zoologique d'Endoume

Musée d'Histoire Naturelle

MASSACHUSETTS—Tufts College Library

MECKLENBURG—Vereins der Freunde der Naturgeschichte

MELBOURNE—Royal Society of Victoria

MONTEVIDEO—Museo Nacional de Montevideo

MONTPELLIER—Académie des Sciences et Lettres

MOSCOU—Société Impériale des Naturalistes

NANCY—Société des Sciences

NAPOLI—Accademia delle Scienze Fisiche e Matematiche

NEW BRUNSWICK—Natural History Society

OPORTO—Annaes de Sciencias Naturaes

PARIS—Museum d'Histoire Naturelle

Société Zoologique de France

Bulletin Scientifique de la France et de la Belgique

PHILADELPHIA—Academy of Natural Sciences

PLYMOUTH—Marine Biological Association

ST. LOUIS, MISS.—Academy of Sciences

ST. PETERSBURG—Académie Impériale des Sciences

SAN FRANCISCO—California Academy of Science

SANTIAGO—Société Scientifique du Chili

STAVANGER—Stavanger Museum

Those marked with * are the additions.

STOCKHOLM—Académie Royale des Sciences

SYDNEY—Australian Museum

TOKIO—Imperial University

Zoological Society of Tokyo

TORINO—Musei de Zoologia ed Anatomia Comparata della R. Università

TORONTO—Canadian Institute

TRIESTE—Società Adriatica de Scienze Naturali

UPSALA—Upsala Universitet.

Société Royale des Sciences

WASHINGTON—Smithsonian Institution

United States National Museum

United States Commission of Fish and Fisheries

WELLINGTON, N.Z.—New Zealand Institute

WIEN—K. K. Naturhistorischen Hofmuseums

K. K. Zoologisch—Botanischen Gesellschaft

ZÜRICH—Zürcher Naturforschende Gesellschaft

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TRANSACTIONS
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INAUGURAL ADDRESS
ON
THE RELATION BETWEEN STRUCTURE and
FUNCTION, as EXAMINED in the ARM.

By PROF. C. S. SHERRINGTON, M.A., M.D., F.R.S., PRESIDENT.

[Read November 11th, 1898].

IN choosing the above for the title of the Address which, as President for the year, I have the privilege to lay before our Society, the term structure has had reference in my mind not to physical or chemical structure so much as to morphological. Morphology has as its object the study of the form of living things, and comparative anatomy it pursues as one of its best and most valuable methods. Of biological studies, those in comparative anatomy are amongst the oldest. The old masters, in pursuing them, delighted to indulge in speculations concerning the use of the structures they described. As the various parts of the mechanisms whose form they examined became known to them, they often had cause to note the suitability of the instrument to its purpose in the life of the creature. They frequently digressed from the immediate object of their treatises to discourse upon the evidences of design in creation of which their observations gave them proof. The Bridgewater Treatises were founded in part to illustrate the beneficent design testified to by the mechanism and vital endowments of the animal body. One of the most famous of these well-known essays was, and has remained, Sir Charles Bell's treatise "On the Hand." Its stately language and wealth of illustration

will long preserve it as a masterpiece of popular exposition of science. Yet every chapter seems far from us as a bygone age; its pages are alive no longer. How has this come about? The facts are true, and therefore living as ever; the style is classical, and therefore never dying. It is the point of view that has suffered change. The question asked throughout is the question that it was the fashion at that time for biologists, and especially anatomists, to ask and to attempt to answer. It was of a phase that was passed through by such students at the period of the "encyclopcædists" and of Rousseau, and lingered for a generation longer. The question asked was one beyond the limit of regions accessible by the means of enquiry that obtains in natural philosophy. It is now generally acknowledged that this kind of teleology lies beyond the province of biology. We desire not to trespass across that limit. We are content to struggle with a humbler problem. The question *why?* is not answered by positive science, but only the question *how?* and sometimes the question *how much?* The physiologist cannot say *why* a muscle contracts, nor define "life." To dogmatise concerning the "why" of a bird's flight, implies the knowing the "why" of the bird's existence. We may be able to see *how* things have happened, or *how* they will happen; and it is a first step in the acquisition of positive knowledge to know that the *ratio rei* is not the "reason why." To confuse natural science with metaphysics is a mischievous mistake for the enquirer, at least for the present and for some centuries to come.

At first sight, function seems in many instances more obviously related to morphological structure than is borne out by a more searching examination of the two. Especially do writings upon mammalian anatomy furnish numerous examples of the looseness of the logic that is

considered sufficient to connect the two. The arm and hand offer a good field for an attempt to institute an enquiry into the connection between the two. I will, therefore, ask you to follow a brief sketch of the morphological structure, and some remarks upon their function; and that done, each can enquire of himself to what measure the morphological structure has helped toward the understanding of the problems of the performance of the function.

If you look at this outline of the human body you will note that in the chest and trunk at least, there is quite evidently a segmental arrangement of the body's structure. If you turn to this picture of the spinal cord lying in the canal of the vertebrae, its composition out of a fore-and-aft series of segments is still more obvious. The segments or metameres of the body appear to possess one spinal nerve apiece. If now we turn to this photograph of the nerves passing from the spinal cord into the limb, we see that a short series of these spinal segmental nerves all go into it. This suggests that the limb is like the trunk composed of metameres essentially arranged segmentally, and built up as is the rest of the body. But there is a difficulty in deciding what part of the limb is constituted by this or by that segment. The segmental nerves that issue from the spinal cord into the limb commingle together in a network or plexus. The brachial plexus, which is before you in the photograph, is compounded of five, sometimes of six spinal nerves. The nerve-trunks that issue from it to the muscles and other structures of the limb have obtained their nerve-fibres from various of the spinal nerves, and each of them from several. To unravel by gross anatomy, this intricate plexus is impossible. Professor Krause, the anatomist of Berlin, has further pointed out that not only was he unable to unravel

the plexus, but he found that each of the great nerve-cords descending from the plexus into the limb is itself a plexus, that defies dissection.

Histology (microscopic anatomy) and physiology can, however, by reason of their finer methods overcome the difficulty thus offered. The physiologist, John Müller, discovered early in this century the "law of isolated conduction" of nerve-fibres. If, therefore, a spinal nerve be excited, *e.g.*, by an electric current conveyed to it as it leaves the spinal cord before it enters the plexus, the fibres that are contributed by it to the various nerves of the limb, will be excited and no other fibres, however close its own may run to them.

The functions of the arm and hand are, however, so multitudinously various that it is well to choose some single, simple one, and to regard it only, letting it stand as a concrete instance and subject for the physiological part of the enquiry. Such an instance may well be chosen in the simple movement I perform when holding my arm out horizontally I flex my fingers, folding them into the palm. The question before us therefore is how is that movement performed, and how does the morphological structure of the part assist us toward explaining in what way the mechanism is actuated?

The flexion of the fingers is due to the contraction of certain muscles situated on the ventral aspect of the forearm and in the palm. In order to simplify our problem still further, let us exclude the palmar muscles. The movement can certainly be performed—as has been proved experimentally in the monkey—without the contraction of the palmar muscles, and this is a further justification for simplifying our problem by their exclusion. The muscles in question, in the forearm, are thrown into contraction by the action of the nerves which pass to them

from the spinal cord. These nerves are bundles of nerve-fibres, while each one of them is a branch of a nerve-cell lying within the spinal cord. The course of these fibres gives important information as to the morphological arrangement of the structure of the limb.

In this way can be discovered exactly what parts of the musculature of the limb are innervated by each segmental nerve. Another plan of investigation is based on the law of degeneration. When an animal cell—for instance, one of the large *Amoebae* obtained in the Red Sea—is divided into several pieces, by tearing with a needle under a dissecting lens, each of the several pieces isolated draws itself together, performs movements, and at first appears to be capable of leading an independent existence. Continued observation, however, reveals the fact that the isolated pieces after a few days die and disintegrate, with the exception only of that portion in which the nucleus remains; that lives on, and later repairs its injured bulk. It is the same with nerve-cells, and probably with all other animal cells. In the case of nerve-cells the occurrence of degeneration in the portion of a cell which has been isolated from the nucleus-containing portion of the cell is, perhaps, the most valuable of all methods for tracing the nerve-fibres to their parent nerve-cells.

The method of degeneration can be combined with that of excitation by electricity. In a few days after nerve-fibres have been severed from their parent nerve-cells, the nerve-fibres, even before they exhibit visible signs of decay, have lost their capacity to respond to stimuli and to conduct the waves of change which are called nervous impulses. In this circumstance lies a means of escape from the embarrassing, for the investigator, accidents of "escape of current." The escape of the electric current from that particular nerve to which it is intended to solely apply, it

is difficult to avoid when these lie in the immediate neighbourhood of other nerve trunks. By rendering these latter inexcitable by reason of their degeneration, the source of fallacy can be completely set aside.

In the above, great stress is obviously laid by implication upon the distribution of the nerves as a key to the morphological, especially to the segmental or metameric architecture of the limb. Why are the nerve-fibres such extremely important indices in this problem? The nerve-cells in the mammal, at least, are peculiar in not evincing reproductive activity after a very early period in the individual's life. They are early differentiated, and are like a committee formed without power to add their numbers. They are laid down when the metamerism of the relatively simply-shaped young individual is more easily traced than in the variously metaphorphosed adult. Thus laid down the nerve-cell keeps in touch with the remainder of that segment to which it belongs in the body by virtue of the enormous power of individual growth of its cell-branches. It does not, as in the young muscle-cell, keep pace with the extension of the body segment in any one direction by means of a repeated fission of nucleus and reproduction, and the forming of a chain of muscle-cells, more or less nutritively independent. To trace such a line of units, although they are closely connected by blood-relationship, is impossible with certainty by any known method. But the nerve-cells remains securely anchored in their original segmental positions, both inside the spinal cord and outside it, in the row of segmentally-arranged spinal ganglia. Growing out from the nerve-cells their nerve-fibres wander distally into skin and muscles, and the main difficulty in tracing the actual limits of the metameres in these last, is that the elements of the adjacent metameres certainly considerably intermingle. So it is also with the ramifica-

tion of the nerve-cell branches within the brain and spinal cord themselves.

It may be conceded, therefore, that the nerve-cell and fibre are trustworthy guides to the plan of the segmental architecture of the body and of the limb. Various other indices have been used, such as the bones, muscles, &c. The former of these led to the view (Goodsir) that the number of digits of the limb told the number of metameres in the limb. As to the muscles, the examination by the nerve-distribution method shows that even the most homogeneous-seeming muscle may be traceable to belong to two and three segments, and be combined from elements of each. It is a point upon which the embryologist is undecided whether the myotoms grow out into the limb-bud; so that embryology is evidently quite unable to say even should the myotoms be proven, as is likely, to grow out into the limb, and so give rise to its musculature, what particular part of the limb musculature is the outcome of any one particular myotom.

What is the result of the analysis by the nerve-distribution method? As regards the muscular part of the metameres some of the results are indicated in the accompanying synopses. The synopses include the range of individual variation, so that although the *e.g.* flexor sublimis digitorum muscle is considered as quadri-segmental, *i.e.*, belonging to four body segments of the brachial region in the *species*, it in any *individual* of the species will belong only to three. To this matter of individual variation I will return later.

The topographical representation of the various elemental movements of the limb in the chain of segments of the spinal cord is always arranged in a definitely ordered sequence. This sequence is exhibited in the accompanying diagram :—

	x	ix	viii	vii	vi	v	iv ^a
<i>Protraction of shoulder</i> - - -						×	×
<i>Abduction of shoulder</i> - - -				×	×	×	
<i>Outward rotation of shoulder</i> -				×	×	×	
<i>Flexion of elbow</i> - - - - -				×	×	×	
<i>Supination of forearm</i> - - -				×	×	?	
<i>Adduction of shoulder</i> - - -		×	×	×	×	×	
<i>Radial abduction of wrist</i> - -			×	×	×	?	
<i>Extension of wrist</i> - - - -		×	×	×	×	?	
<i>Inward rotation of shoulder</i> -			×	×	×		
<i>Extension of fingers</i> - - - -		×	×	×	×		
<i>Extension of elbow</i> - - - -		×	×	×	?		
<i>Flexion of wrist</i> - - - - - ?	?	×	×	×	?		
<i>Retraction of shoulder</i> - - -	×	×	×	×	×		
<i>Pronation of forearm</i> - - - ?	?	×	×	×	?		
<i>Flexion of fingers</i> - - - - ?	?	×	×	×			
<i>Interosseous flexion of fingers</i> -	×	×	×				
<i>Adduction of fingers</i> - - - -	×	×	×				
<i>Abduction of fingers</i> - - - -	×	×	×				

Certain movements of the limb are not seen at all in the stimulation of individual motor roots: *e.g.*, in many monkeys no root gives extension of the pollex, and in some monkeys no root gives extension of the wrist, and I have met with an individual in which no root evoked extension of the fingers.

The range of the spinal innervation of the skin and the muscles covering, and moved by and moving, the joints of the upper limb, is shown in the accompanying conspectus. The sensory innervation of the deep structures may be looked on as similar in segmental range to the motor innervation of the muscles.

Number of spinal nerve-root -		Thorax.				viii	vii	vi	v	iv	iii
		iv	iii	ii	i						
		xii	xi	x	ix						
Shoulder	skin -	*	*	*				*	*	*	*
	muscle -				×	×	×	×	×	×	
Elbow	skin -			*	*	*	*	*	*		
	muscle -				×	×	×	×	×		
	flexors -					?	×	×	×		
	extensors				×	×	×	?			
Wrist	skin -				*	*	*	*			
	muscle -			×	×	×	×	×			
	flexors -			?	×	×	×	?			
	extensors				?	×	×	×			
Fingers	skin -				*	*	*	*			
	muscle -			×	×	×	×	?			
	flexors -			×	×	×	×				
	extensors			?	×	×	×	?			

I have given recently a synopsis of the spinal nerve-supply of the muscles of the upper limb, which shows that the muscular tissue of the limb is arranged in a number of rays, a ray for each metamer contributing to the limb. It shows that of these rays the ones which lie tailmost in the fore-and-aft series are the longest, that is, extend to the extreme free apex of the limb, whereas the foremost, the most rostral, pass only as far as the upper arm, the next only as far as the elbow, the next only as far as the wrist. The four last, or most aboral rays, all contribute to the musculature of the hand in *Macacus rhems*, the common Rhesus monkey.

But when we come to enquire how these units of the segmental architecture of the limbs, these muscular rays, are related to the physiological or functional units of the limb-musculature, it is at once obvious that the extent and boundaries of the two do not coincide. The individual muscles of the limb are functional elements of its structure as a physiological machine. But each of these functional elements is compounded of portions of several rays or myotoms. Moreover, the boundaries between the myotoms do not correspond with the intervals of muscles, or even between muscle-groups.

The same want of segmental separation is evident when we examine the location of the nerve-cells which innervate the individual muscles. Each of the segmental spinal nerves which supplies the musculature of the limb leaves the spinal cord in the form of a row of rootlets, which together build up the motor-root of the nerve. Excitation by electric currents of anyone of these rootlets or filaments, that contribute to the formation of the motor-root, produces a movement in the limb which resembles closely the movement produced by excitation of the whole root. The same muscles are thrown into contraction as when

the whole root is excited; but the action of each muscle is feebler. The collection of nerve-fibres contained in the rootlet is therefore, in miniature, a collection like that contained in the whole root. This fact must be taken together with the fact that, as can be shown by degeneration experiments, the fibres contained in each rootlet represent the nerve-fibre processes, or axis cylinder processes, of the motor nerve-cells lying in that particular transverse plane or level of the spinal cord, from which the rootlet makes its emergence. The two facts together show that the nerve-cells which innervate the different muscles belonging to any one myotom in the limb, lie commingled together, so that any one section through the spinal cord, taken at right angles to its length, will meet nerve-cells belonging to all the muscles represented in that segment. This is the same as saying that the nerve-cells belonging to any one limb-muscle, lie not gathered together at any one particular level of the spinal segment, but scattered throughout its length. And, inasmuch as each muscle is innervated from several segments, the nerve-cells for each muscle are scattered in a continuous series through the length of a series of spinal segments; and throughout this extent are commingled with the cells of a great number—in some cases as many as forty and more—of other muscles.

It is, therefore, evident how it comes about that no traumatic injury of the spinal cord can ever paralyse a single muscle alone and apart from its fellows. Even the severance of a whole single motor nerve-root cannot paralyse a single limb-muscle; the effect of such an injury is to partially impair a large number of the muscles.

It has been urged by many observers that the motor nerve-fibres gathered together in each motor spinal-root are a collection connected for functional co-operation.

These writers attach, therefore, a clear and simple functional meaning to this collection which composes the spinal root. They point to the fact that stimulation of this root or that root produces a movement of the limb which is of some definite kind, such as a flexion of the elbow, flexion of the fingers, &c. The movement evoked they consider one which indicates that the nerve-fibres associated together in the motor root are associated there in order to, by acting contemporaneously, execute a highly co-ordinate functional synergy of muscles. By synergetic muscles are understood those muscles which, in natural movements, contract harmoniously together to execute a movement. I find nothing which is really valid evidence for this view and much to the contrary. The mere inspection of a movement of the limb without further analysis of it is very insecure a guide by which to judge of its natural character. The joints and muscles of the limb have been evolved contemporaneously and together in the course of the history of the individual and of the species. No muscle can, therefore, be thrown into action which will move the limb in any which is an unnatural direction. Our knowledge of the synthesis of the natural movements of the body out of the contractions of the individual muscles is extremely meagre. The names given, for instance, to many of the muscles of the human arm are misleading rather than helpful as regards the movements they produce. The resolution of the combined movements into their components require data hardly obtainable, because requiring isolated contraction of individual muscles in life, and the alteration of the lengths and tensions and elasticities of the muscles after death, precludes the possibility of dealing with them even approximately accurately by examination in the dissecting-room. Thus few realise that the gastrocnemius muscle

is a flexor of the hip, although this can, as a fact, be experimentally shown; and the mathematical treatment of these problems is far from easy.

Against the view that any one spinal motor-root represents the motor spinal nerve cells concerned in some particular highly co-ordinate functional synergy, rise a number of facts. These I have detailed elsewhere. Among them are the sudden change which in some motor-roots occurs as the stimulation of the individual rootlets composing the root is undertaken in serial order; the upper filaments of the root producing one movement, the lower series another movement; the upper filaments of the root produce a movement like that produced by the filaments of the root next above, the lower like that of the root next below. Here, then, the collection of the root would contain two functional groups representing two synergies, and the upper one would be simply a replica of that of the functional synergy of the root next above, and the lower that of the root next below. Then the combination of a piece of the diaphragm muscle with supination of the wrist, of flexion of the wrist with extension of the fingers, are bizarre effects unknown in any reflex movement, or movement produced by excitation of the brain. The combination of supination at the wrist with flexion of the hand, is of itself an unusual movement, that usually requires some attention for its execution.

The degeneration experiments show that in some muscles the number of motor nerve-fibres given by a spinal-root to a muscle is too small to evoke from the muscle any contraction at all obvious to inspection. Cases occur where a limb muscle receive one, two, three, four, or five motor fibres from a particular root; allow to each of these motor nerve-fibres a dozen muscle-fibres, it

is easy to understand that sixty muscle-fibres scattered in a muscle consisting of many thousands may cause no perceptible tightening of the tendon; they may simply stretch or compress adjoining inactive and elastic fibres. The degeneration of these few fibres I look upon as strong evidence of the morphological character of the overlap; the paucity of the fibres is one of the many facts which indicate that the distribution of the motor-roots is arranged on a segmental plan in accordance with the terms of a bequest dating back to a time when the present environment of the limb, especially in its Mammalian form, had no preponderant weight in the shaping thereof. As regards functional value this character of the Mammalian limb is on a par with details of structure which are not specific, and, therefore, with other details of structure outside these immediately acquired by the species, not to be considered as of necessity of functional importance. The functional use of the contribution of one or two nerve-fibres to a muscle requiring hundreds is difficult to see; the probability of the occurrence of such poverty-stricken contributions is, on the view of the morphological necessity of the ray-arrangement of the limb musculature, so high as to be only what might have been expected from theoretical considerations. The fact that certain of the motor-roots of the limb contribute fibres to the innervation of certain muscles in such scanty number as to be ineffective for movement is a further argument for the morphological rather than functional character of the motor-root distribution in the Mammalian limb. A number of motor-fibres, too small to evoke appreciable movement in a muscle when excited electrically, will hardly be effective for movement under the action of the will.

Strongly militant against the functional theory of the motor-root is the frequent occurrence and wide range

of individual variation in the movements produced by excitation of the roots, and in the distribution of the nerve-fibres composing a root to the muscles of the limb.

In experiments on the plexuses, it is rare to find two consecutive individuals of the same species that possess a similar root distribution. The plexus in any species requires for description to be grouped into classes. For my purpose I have found two classes enough, a class of individuals in which the plexus is *pre-fixed* and a class in which it is *post-fixed*. Thus, in some individuals, the supinator brevis is innervated from the 6th and 5th cervical nerves, in others from the 6th and 7th. In the former case the plexus is of pre-fixed type, and when one muscle or one part of the plexus is pre-fixed, all the rest of it is pre-fixed, and conversely, when one part is post-fixed, all is post-fixed. In the second instance given above, the supinator brevis is post-fixed, that is, its nerve-cells are fixed in segments further aboral in the series than in the individuals with pre-fixed plexuses. Presumably the muscle itself therefore is built of myotoms more aboral in the series than in the muscle in the pre-fixed individuals. But instead of two classes, there might be made a very large number of classes were it worth while to separately distinguish them, for between the extreme cases of post-fixed type and the extreme examples of pre-fixed type extend a numerous series of intermediate individuals; in fact, any and every intermediate degree of type seems to exist. The extreme of post-fixed type passes over into the comparatively rare individual with an additional segment altogether, *e.g.*, the cat with fourteen ribs, which is not at all an uncommon find in the laboratory. Never a year passes without our meeting with four or five such. This frequency of individual variations exhibits in an almost ludicrous aspect the view that each motor spinal

root is a collection gathered together for a functional purpose, and representing a particular highly co-ordinated movement of the limb. Contrary to any such hypothesis, it shews that for the functional mechanism of the limb it is immaterial whether this or that particular group of muscles is represented in a particular spinal root or not represented in it. The *absolute* segmental level is variable over the range of nearly a whole segment's length; the *relative* segmental position is, however, inviolably preserved. Thus *flexor carpi ulnaris* may get fibres from as high as the 6th cervical segment, or it may not, but it never extends so well forward, so far rostrally, as *flexor carpi radialis*, and this latter never extends so far aborally as *flexor carpi ulnaris*, even when it is most post-fixed; that is the region of out-flow for the spinal nerve-fibres to *flexor carpi ulnaris* lies rather more aborally than that of the out-flow of *flexor carpi radialis*, and this mutual segmental position of the muscles is maintained whether the plexus be post-fixed or pre-fixed.

The idea at root of the supposition, that the motor-root is a functional collection of nerve-fibres, seems to be that juxta-position in space is advantageous for co-ordination of action. The material of support for this idea is very slender, and there are many facts which show that mere spatial separation offers no difficulty for the physiological mechanism of co-ordinate and synchronous activity. The great respiratory centre in the spinal bulb, and the various subsidiary spinal respiratory centres, lie very far remote one from another. Yet how accurately do they harmonise in their activity? Their co-ordination consists rather in the fact that they are all chemically tuned, so to say, to the same pitch or note of stimulus. They differ from all the other bulbo-spinal centres, and agree among themselves in their peculiar sensitivity to the stimulus of venous

blood. So also in the case of the individual spinal nerve-cells, innervating a particular muscle, we suppose, that their co-ordinate action and synchronous discharge depends rather on some physiological quality common to all which cannot be accorded to them by mere spatial arrangement.

A question that obviously presses for answer, is whether when a muscle contracts either reflexly or voluntarily, all the parts of it innervated from all the spinal roots contract together, or whether some parts of it contract for some movements, and others for other movements, and so on, and so whether the segmentally different parts of the muscle are used severally for different functional actions. In reflex movements, and in movements evoked from the cortex of the brain, we can say that the discharge of motor impulses to a pluri-segmental muscle of the forearm, or wrist, or hand, is always pluri-segmental, and involves the whole length of the serial group of intra-spinal nerve-cells which innervates the muscle extending through its full number of segments of the cord. The afferent and cerebral channels of the cord treat the pluri-segmental motor stations or nuclei of these limb muscles as entities of homogeneous structure, as in fact, physiological units.

This serves to emphasise the physiological homogeneity of limb-muscle and nerve-trunk, and the physiological heterogeneity, in spite of morphological unity, of the spinal nerves-root in the limb-region of the body. The spinal nerve-roots of the thoracic region are, from the physiological point of view, less heterogeneous. The peripheral nerve-trunk is the *physiological* collection of nerve-fibres, *e.g.*, flexors collected together, vasodilators, included with motors to muscles, &c. The *nerve-root* is the *morphological* collection, it contains commingled into one such heterogeneities as adductors of the hallux with protrusor pelvic muscles.

Similarly with the skin, the median nerve-trunk supplies a patch of the palm that has obviously functional unity, but 1st thoracic nerve-root supplies such incongruities as the front of the little finger and of half the ring finger, together with the tip of the point of the elbow.

It is the formation of functional collections of nerve-fibres (peripheral nerve-trunks) out of morphological collections (nerve-roots) which is the meaning of the interlacements of adjacent spinal segmental nerves in the limb plexuses. The reply to the frequently asked question as to the explanation of the distribution of the spinal nerves of the brachial and pelvic limbs by plexuses, while the spinal nerves of the trunk region are not distributed by plexuses, is in my opinion as follows. In the trunk region the innervation of the muscles of the skin is, as regards the distribution in them of the segmental nerves, a system of comparatively slight overlap: the peripheral territory of each segmental nerve—especially each motor territory—is confluent with, but does not mingle nearly so widely with the neighbour territories as in the limb regions. That is, in other words, each several area of skin and of muscle, especially of the latter, has in either of the limbs a more pluri-segmental spinal innervation than a comparable area in the trunk. The anatomical mode of innervating a definite area of tissue is, as we know, by means of collecting the nerve-fibres for the region into a nerve-trunk; where the innervation is pluri-segmental the nerve-trunk will naturally be combined from components of several segmental nerves—where several such areas co-exist several pluri-segmental nerve-trunks will be formed and the separate segmental nerves will be split up into components, which become redistributed in the combinations which constitute the pluri-segmental

nerve-trunks of the region—as, for instance, in the brachial reigon. The brachial and lumbo-sacral plexuses are an anatomical result of the greater degree of overlap, especially in the distribution of the motor part of their spinal nerves, obtaining in the limbs as compared with other, *e.g.*, the trunk regions of the body.

Enough has been said, I imagine, to let us see how little light is thrown upon the function and uses of the limbs by study of their segmental architecture. It is especially when the anatomist confines his attention to minute examination of one limited group or type, that he seems to become most prone to dogmatise concerning function, and his arguments have to be received, unless checked by actual experiment, with the extremest caution. In a certain sense, it would seem that the creative power of nature can mould with such superfluity of resource the, to us, who cannot construct it, pricelessly valuable material that heredity and life bequeath, that she has various ways open for compassing the same required end. Thus a segment more or a segment less offers little difficulty to her. The individual with a segment less or segment more betrays neither his defect nor his surplus by any trace of disturbance of function; his idiosyncrasy goes unsuspected either by himself or his neighbours, physiologists and morphologists though they may be. When the “how” of the processes of function and of structure is nearer answer than at the present time, this may appear to us less strange than now. But for the present it does seem clear that the laws of morphological structure and of physiological structure, though they must be fundamentally correlated, are much more different than many are accustomed to think of them and say. The width of the chasm between the two is probably best felt by the zoologist who holds in view in his mind’s eye the vast range of comparative

structure in animal forms, and by the physiologist who, studying the body in its aspect as a mechanism for liberating the locked energy of chemical molecules in forms of material, and perhaps of mental, life finds an extravagance of material and a riot of design that baffles his description almost as much as his comprehension. But he always remembers that his question is not *why*, but *how*. When Helmholtz, after his investigation of the optics of the human eye-ball, drew attention to the manifold optical defects in that structure, and wrote that an optician would discharge a workman for producing so optically imperfect an instrument, it appeared to some that such a criticism was impious in character. The attribution of impiety to such expression shews how liable to confusion are the two lines of enquiry of the *why* and *how*. As Helmholtz himself points out in the most beautiful of passages, so inconceivably admirable is the wonderful mechanism of the nerves and brain upon which the optic parts of the eye-ball throw their relatively imperfect pictures of the visible world, that despite these defects, the sense of vision results, with all its marvels, and builds the chiefest basis and scaffold for the uprearing of the indescribable edifice of the human mind.

TWELFTH ANNUAL REPORT of the LIVERPOOL
MARINE BIOLOGY COMMITTEE and their
BIOLOGICAL STATION at PORT ERIN.

By Professor W. A. HERDMAN, D.Sc., F.R.S.

THE Report affords an opportunity of laying annually before the Biological Society, our subscribers, and the larger public of Liverpool and the neighbourhood, not only a statement of the statistics of the Biological Station during the year, and a record of the work done, but also an outline of such plans for the future, extensions of the work, and promising investigations as seem to the Director worthy of being published, in the interests of Biological science, in order that some possibly who are able may follow up the suggestions, and that others who can afford it may, if they care, provide funds to enable special pieces of work to be undertaken.

The year's work will, as usual, be reported upon first, and then certain proposed investigations and more general matters will be discussed (see p. 43).

THE STATION RECORD.

During the past year the following naturalists have worked at the Station, in addition to the Curator, who has been constantly in attendance :—

DATE.	NAME.	WORK.
<i>January</i>	Mr. I. C. Thompson, Liverpool ...	... Copepoda.
—	Professor W. A. Herdman, Liverpool ...	... General.
—	Dr. Christophers, Univ. College*...	... General.

* Univ. College after a name indicates that that worker made use of the "table" secured by the College Council.

DATE.	NAME.	WORK.
<i>March.</i>	Mr. I. C. Thompson 	Copepoda.
—	Prof. W. A. Herdman 	Comp. Ascidians.
—	Mr. F. J. Cole, Univ. College 	Comp. Ascidians.
—	Mr. R. L. Ascroft, Lytham 	Fishes.
<i>April.</i>	Mr. F. J. Cole, Univ. College 	Comp. Ascidians
—	Mr. A. R. Jackson, Univ. College 	Arachnida.
—	Mr. J. C. Mann, Univ. College 	General.
—	Prof. W. A. Herdman 	Comp. Ascidians.
—	Mr. Mundy, Owens College 	General.
—	Mr. I. C. Thompson 	Copepoda.
—	Mr. A. O. Walker, Colwyn Bay 	Amphipoda.
<i>May.</i>	Rev. L. J. Shackleford, Clitheroe 	Mollusca.
<i>June.</i>	Rev. T. S. Lea, Liverpool 	Alge & photography
<i>July.</i>	Mr. F. J. Cole, Univ. College 	Comp. Ascidians.
—	Rev. T. S. Lea 	Alge, &c.
—	Prof. W. A. Herdman 	Comp. Ascidians.
—	Mr. I. C. Thompson 	Copepoda.
—	Mr. A. O. Walker 	Amphipoda.
—	Mr. J. A. Clubb, Liverpool Museum 	Actinia.
—	Mr. R. L. Ascroft 	Fishes.
<i>August.</i>	Mr. C. Crossland, Clare College, Camb. 	General.
—	Mr. R. L. Ascroft 	Fishes.
—	Rev. L. J. Shackleford 	Mollusca.
<i>September.</i>	Mr. H. Yates, Manchester... 	Polychæta & Plankton.
—	Rev. L. J. Shackleford 	Mollusca.
<i>October.</i>	Mr. I. C. Thompson 	Copepoda.
—	Prof. W. A. Herdman 	General.
—	Mr. F. J. Cole, Univ. College 	Comp. Ascidians.
<i>December.</i>	Mr. I. C. Thompson 	General.
—	Prof. W. A. Herdman 	General.

The work of a number of these Naturalists will be found discussed further on in this report.

THE CURATOR'S REPORT.

Mr. H. C. Chadwick entered upon his duties early in January, 1898. Since then he has kept the Station in excellent condition, has added greatly to the attractiveness of the Aquarium, has carefully attended to the wants of

workers in the laboratory, and has done a considerable amount of collecting on the shores and in the bay. A most effective addition to the collecting apparatus which can be worked from a rowing boat in the bay is a small iron trawl of $4\frac{1}{2}$ feet beam, and fitted with the cod-end of a shrimp net. This is lighter to pull than a dredge, sweeps a greater area, and gives better results.

The Lords Commissioners of Her Majesty's Treasury have kindly presented to the library of the Station the three large quarto volumes containing the well-known elaborate Report upon the "Challenger" Amphipoda by the Rev. T. R. R. Stebbing, F.R.S., a classic work in marine biology.

Mr. Chadwick reports as follows :—

"The Port Erin Biological Station has been open every week day from January 24th to the present. The Laboratory, together with the instruments, dredges, and other implements has been kept in a clean and efficient condition. A few additions have been made to the stock of reagents, and the supply of all has been kept up to the requirements of workers. A few additions, in the shape of reprints and one volume (purchased) have been made to the library. To all donors an acknowledgement was promptly sent.

"Meteorological observations have been taken and carefully recorded twice almost every day, the very occasional omissions being caused by the Curator's absence on a dredging excursion.

"In January, the temperature of the sea was almost uniformly 2° higher than that of the air, while in February it averaged 4° to 5° higher. In March, it averaged about 3° higher, and in April, 1° higher. From the beginning of May to the end of September, the temperatures of air and sea averaged the same. The greatest disparities occurred in May, when, during the afternoon of the 13th,

the temperature of the sea was 11° higher than that of the air, and during the afternoon of September 5th, when the temperature of the sea was 12° less than that of the air. The density of the sea-water has shown very little variation, and only twice have I noticed a slight loss of density to occur *immediately* after a few hours rain. The average may be stated as 1.026.

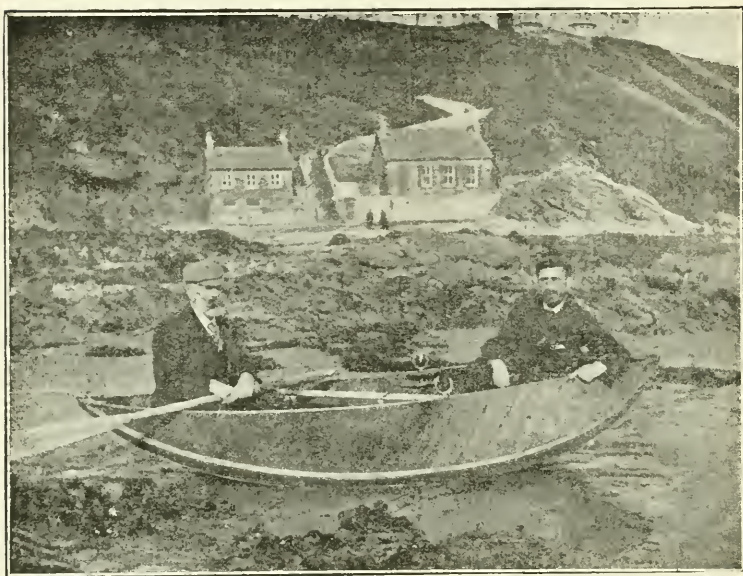


Fig. 1. The "Shellbend" punt on the shore—starting for a "plankton" trip. [From a photo by Mr. Edwin Thom] son.]

"The 'Shellbend' folding boat has been frequently used, and is still in a thoroughly seaworthy condition, though beginning to show signs of wear. In launching and housing the boat residents and many visitors have rendered willing assistance.

"In spite of much rough weather, over fifty tow-nettings have been taken and carefully preserved. The Curator's

time has been so fully occupied with other duties that he has not yet been able to carry out the projected careful examination of these week by week. *Sagitta* appeared in great abundance on June 21st, but has occurred only sparingly since. *Pleurobrachia* has occurred in all the gatherings from early spring onwards, and the same remark applies to *Appendicularia*.

"The Scyphomedusæ have been very sparingly represented this year. Several trips were taken in the 'Shellbend' in quest of *Aurelia aurita*, but none were obtained. A large number were, however, cast ashore on one day early in July. About twenty large specimens of *Rhizostoma pulmo* were cast ashore early in March, in the gastric canals of each of which were a number of specimens of *Hyperia galba*, and one living specimen was seen in the bay on October 12th. *Cyanea capillata* and *Chrysaora isosecles* have not come under the Curator's notice.

"Eleven dredging excursions have been undertaken in a small boat, and hauls taken in various parts of the bay, outside as well as inside the break-water. In one such excursion the following species were taken:—*Clytia johnstoni*, *Obelia geniculata*, *Asterias rubens*, *Astropecten irregularis*, *Ophiura ciliaris*, *O. albida*, *Echinus esculentus*, *E. miliaris*, *Nereis* sp., *Portunus pusillus*, *P. puber*, *Stenorhyncus rostratus*, *Eupagurus bernhardus*, *E. prideauxii* with *Adamsia palliata*, *Crangon vulgaris*, *Virbius varians*, *Galvina farrani*, *Facelina drummondi*, *Aplysia punctata*, *Rissoa parva*, var. *interrupta*, *Phasiarella pullus*, *Sepiola* sp., egg capsules of *Loligo forbesi*, with developing embryos.

"The frequent occurrence of rough weather has prevented the Curator from gaining more than a general idea of the nature of the bottom of the bay beyond the lowest tide mark. The shoreward border of the great sea-weed bed,

which trends in a south-westerly direction from the spot where the drainage of Port Erin is discharged, has, however, been traced.

“Shore collecting has been carried on at intervals all through the year, and much knowledge gained of the precise localities in which many species may be found.

“On August 15th the buoy at the end of the breakwater was brought ashore for its annual cleaning, and with the assistance of Mr. C. Crossland of Clare College, Cambridge, the Curator took from its flat bottom the following species :—

“*Sycon compressum*, *Bougainvillia ramosa*, *Coryne* sp., *Tubularia larynx*, *Eudendrium ramosum*, *Obelia geniculata*, *Clytia johnstoni*, *Sertularella rugosa*, *Nereis* sp., *Terebella* sp., *Sabella* sp., a Nemertine, *Bicellaria ciliata*, *Scrupocellaria* sp., *Membranipora*, several Amphipods and Isopods, *Nymphon gracile*, *Doto fragilis*, *Ciona intestinalis* (very abundant), *Ascidia mentula*, *Styela grossularia* (abundant), *Corella parallelogramma*, and at least half-a-dozen as yet undetermined species. Such a large assemblage of animals, over thirty species, formed a striking commentary on the efficacy of the anti-fouling paint with which the buoy had been covered, and which, the harbour master said, had been guaranteed by the makers to poison everything.

On November 2nd there was another incursion of the Amphipod *Orchestia gammarellus* from the shore. As on previous occasions they swarmed all over the laboratory.

“The number of visitors to the Aquarium again shows a substantial increase, over 500 having paid for admission. The constant care which its successful maintenance has entailed has been repaid by the interest shown by the visitors, and by the favourable comments of many who had visited it in former years. A considerable proportion

of the visitors were families of children who were brought by their parents to learn something about the structure and habits of the animals seen in their rambles amongst the rocks on the shore. The fish-hatching tanks have attracted a great deal of attention, and the many questions asked by the visitors—questions based on information gained from newspapers and magazines—showed that the interest in fish-hatching is becoming wide-spread.

“We also had in July a visit from a number of the pupils of the Arnott Street Board School in Liverpool, the party being under the guidance of Rev. T. S. Lea. The Curator hopes before next season to arrange a series of tanks, for workers at the Station, through which seawater will constantly circulate.

“The publication of a price list of specimens has not as yet had very much result, comparatively few orders having been received. The list, thoroughly revised and with prices lowered as much as possible, is now appended to this report.”

ADDITION TO THE LABORATORY.

During the past year we have added very considerably to the accommodation for students at the Biological Station by placing a wooden staircase and a new upper floor in the laboratory. This upper chamber is sub-divided by partial wooden partitions into five alcoves, each having a small window in the roof, and each containing a fixed work table for one student, measuring over 8 feet by 3 feet. This increase of accommodation permits the Committee now to carry out a plan they have long had in view, viz., to arrange an

EASTER STUDENTS' PARTY.

It is proposed that any persons who desire to join as students should pay (in addition to their own expenses)

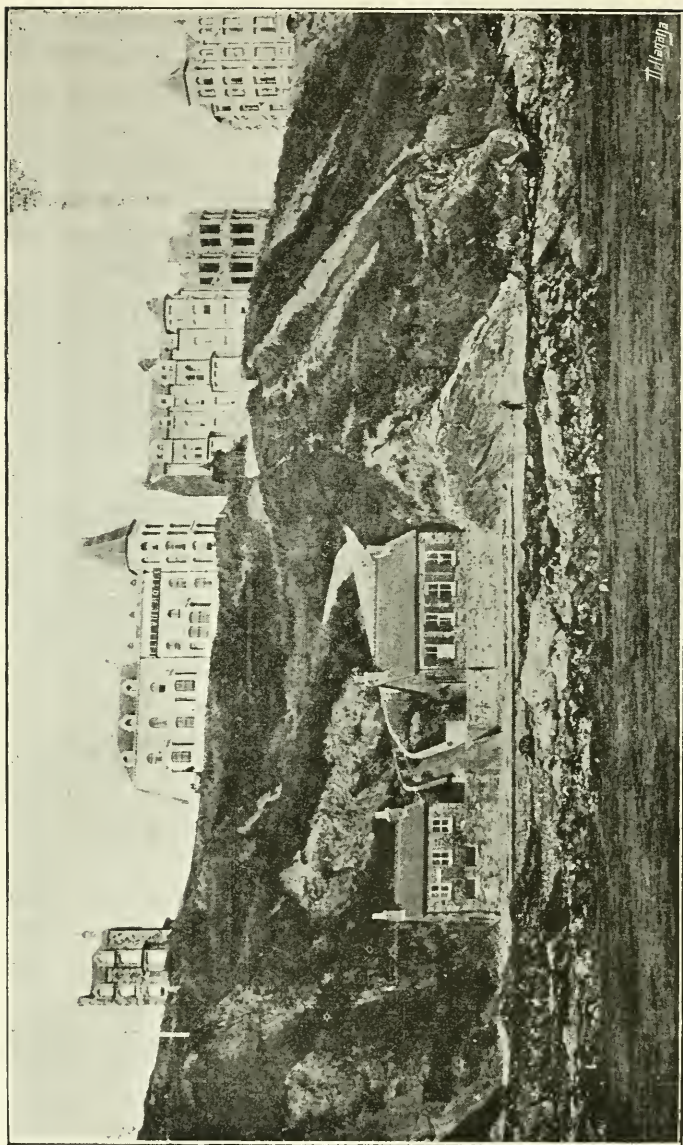


Fig. 2. Port Erin Biological Station and its surroundings, at low tides, from the sea. [From a photo by Rev. T. S. Lea.]

a small fee to the funds of the institution. * Dredging, tow-netting, and shore collecting expeditions will be organised on certain of the days, according to tides and weather; and at other times there will be occasional lectures and demonstrations in the Biological Station, and opportunities for laboratory work. Several members of the Committee have promised to join the party, and the scheme offers a very unusual opportunity for collecting and studying in the company of specialists which will probably be of great service to junior students of marine biology and to some amateurs.

DREDGING EXPEDITIONS.

In addition to frequent dredging and trawling from small boats in the bay, the following expeditions in steam trawlers have been organised:—

I. April 9th, 1898. In Fisheries steamer “John Fell”—

1. Two miles off Fleshwick, 20 faths. (2 hauls of shank net).
2. Two miles off Dalby, 35 faths., bottom mud (with shank net).
3. Two-and-a-half miles off Dalby, 40 faths., bottom mud (with fish trawl).

II. April 11th, 1898. In Fisheries steamer “John Fell”—

1. One to two miles off Dalby, 20-35 fathoms.
2. Between Bradda Head and Calf Sound, 17 faths.

III. April 20th, 1898. In steam trawler “Tudor Prince”—

From three to five miles off Entrance to Glen Meay, 22 to 30 faths.

* A circular, giving all particulars, will be issued. Apply to the Curator.

IV. July 16th, 1898. In steam trawler "Rose Ann,"
when we dredged and trawled at the following
localities :—

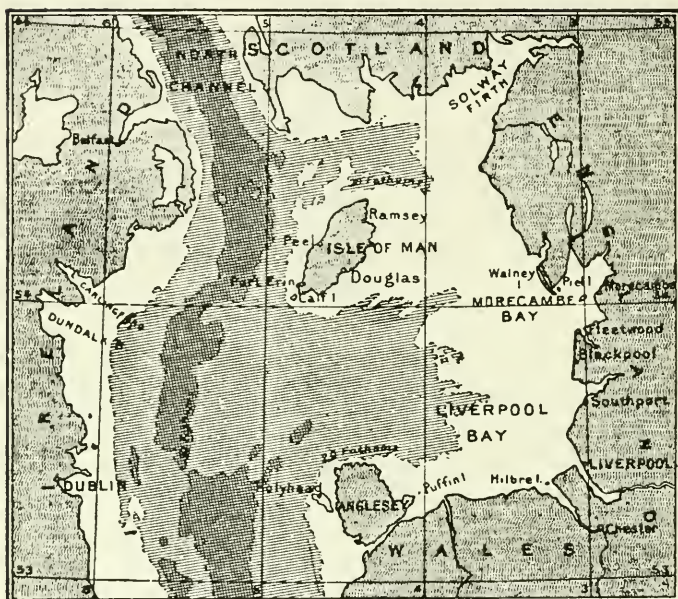


Fig. 3. Plan of the L.M.B.C. District.

1. Two miles south of Spanish Head, 17 faths.,
a neritic bottom.
2. Four miles east of Port St. Mary, 18 faths.,
many Ophiuroids.
3. Four miles east of St. Ann's Head, 20
faths., gravel bottom.
4. Three-quarters of a mile east of St. Ann's
Head, 13 faths., melobesia bottom, drag-
ging inwards to Algæ and Polyzoa, with
enormous masses of *Perophora* (chiefly on
Vesicularia spinosa) and other Ascidians. In
this last haul, 14 species of Tunicata were

obtained, as follows:—*Perophora listeri*, *Clavelina lepadiformis*, *Ascidia mentula*, *A. scabra*, *Corella parallelogramma*, *Molgula* sp., *Molg.* sp., *Polycarpa pomaria*, *P. comata*, *Stylopsis grossularia*, *Amaroucium proliferum*, *Aplidium* sp., *Diplosoma* sp., and *Botrylloides* sp.

We still have living healthily in the tanks specimens of the following moderately deep-water forms obtained at one of the dredging expeditions last summer:—*Stichaster roseus*, *Porania pulvillus*, *Venus verrucosa*, *Pectunculus glycymeris*, and *Aporrhais pes-pellicani*.

The following rare or interesting animals have been kept in the tanks of the Aquarium house during the year:—

Zoothamnion dichotomum.

Ephyrae of *Aurelia aurita*.

Lineus gesserensis.

Carinella annulata.

Phyllodoce laminata.

Cucumaria hyndmanni.

Hyperia galba.

Eggs of *Loligo forbesi*.

The sea slugs *Galvina cingulata* and *Eolis farrani*.

Lepadogaster decandollii.

The Amphipod *Tritæta gibbosa*, infesting colonies of *Amaroucium argus*.

A specimen of *Eupagurus prideauxii* (the hermit crab), which had *Adamsia palliata* (the cloak sea-anemone) on its shell, after being kept for some time, adopted a new shell—the *Adamsia* accompanying it.

Early in July great shoals of young *Gadus virens* (the saithe) and *Pleuronectes platessa* (the plaice) were seen close to the shore, in front of the laboratory. They were

feeding upon the "fairy shrimp," *Mysis inermis*, which swarmed at the time in countless thousands. Mr. Andrew Scott finds, on the Lancashire coast, that young Herrings, 2 to 3 inches long, feed largely upon *Mysis*. There can be no doubt that this Crustacean is an important fish food.

NOTES ON WORK DONE AT THE STATION.

Mr. J. A. CLUBB, M.Sc. (Vict.), is now carrying out his investigations on the structure and variations of sea anemones upon material from Port Erin. He spent some time at the station in summer collecting material for his work, the first part of which has just been published in our twelfth volume.

A quotation from Mr. Clubb's report to me runs:—

"I had a very good collecting time during the remainder of my stay at Port Erin. We dredged *Adamsia palliata*, obtaining about half-a-dozen good specimens, and I succeeded in fixing three of them well expanded. I did not, however, get *Corynactis viridis*, although out dredging for it two or three times. I got a number of the littoral forms (five different species), and have fixed them all for dissection and histological work."

Mr. J. NEWTON COOMBE, late Chairman of the Sheffield School Board, has been supplied frequently with gatherings of diatoms from the surface during the spring and early summer. From this material he has been making observations upon the life history and reproduction, and his results, he informs me, are nearly ready for publication.

Mr. A. O. WALKER sends me the following "Report on Malacostraca in 1898" as the result of his work this year:—

"There has been a remarkable scarcity of Amphipoda this summer on the coasts of Liverpool Bay within a mile of the shore. At Bull Bay, Anglesey, in June; Port Erin

in July; and Colwyn Bay in September, very few individuals were taken in the bottom tow-net. It is possible that this may partly account for the small takes of fish at Rhos Weir this summer.

“The following are the more noteworthy Crustacea taken during the past season. :—

“*Mysis longicornis*, M. Edw. [G. O. Sars, Middelhavets Mysider, p. 22 (separate copy) pls. ix and x.]

“This species, hitherto recorded only from the Bay of Naples, may be at once distinguished from all the other British species of the old genus *Mysis*, except *M. (Neomysis) vulgaris*, J. V. Thompson, by the absence of a notch, or cleft, at the end of the telson, and from that species by its telson having the end rounded, and the margins furnished with closely set setæ of unequal length. On the other hand, the resemblance of the telson and antennal scales to the genus *Leptomysis* is remarkable. The female of this species is practically indistinguishable from the same sex in *Leptomysis apiops*, G. O. Sars, except by the length of the spine on each side of the two small central spines at the apex of the telson. These in *M. longicornis* are but little longer than the other long spines on the margin, while in *L. apiops* they are quite twice as long. The resemblance extends to the curious trigonate points of the spines round the end of the telson, which I have not observed in any Crustacean except these two. A new genus is required for this species, the characters of which do not agree with any of the existing genera of Mysidæ.

“One female was taken in the bottom tow-net at Bull Bay, June 10th, 1898, in 20 fath. Length 6 mm.

“*Cumella pygmaea*, G. O. Sars. Several females and three males taken at the same time and place as the last. Not previously recorded in Liverpool Bay.

“*Argissa hamatipes* (Norman); = *Syrrhoë hamatipes*,

Norman, Brit. Assoc. Report on Shetland Dredgings, 1868, p. 279; = *Argissa typica*, Boeck, Crust. Amph. Bor. et Arct. 1870.

"A single male specimen was taken in the bottom tow-net at Colwyn Bay in $2\frac{1}{2}$ fath., Sept. 13th, 1898. I have Dr. A. M. Norman's authority for saying that his species is identical with Boeck's, and I have seen the type specimen. Previously recorded from the Isle of Man coast in 12 fath.

"*Gammarus duebeni*, Lilljeborg.

"A single specimen, dredged off Glen Meay, about four miles from land in 22—30 fath., April 20th, 1898.

"There is, perhaps, no aquatic animal which appears to be able to exist under such different conditions as this species. I have specimens collected by Dr. R. F. Scharff, in Lough Doon, Co. Kerry, "about 1,000 ft. above sea-level;" Mr. Thos. Scott records it from Loch Ruan, near Campbeltown, "several hundred feet above sea level" (Fifteenth Ann. Rep. of the Fishery Board for Scotland, Part III., p. 322); and Prof. G. O. Sars says that it occurs "in brackish pools among shore rocks, considerably above high-water mark," and in "warm springs of south Greenland." (Amphipoda of Norway, p. 503).

"*Pleonexes gammaroides*, Sp. Bate.

"Several specimens taken at Port Erin by Mr. Chadwick, in April, 1898, probably in rock pools. Not previously recorded in the Isle of Man."

MR. ARNOLD T. WATSON, F.L.S., reports to me:—

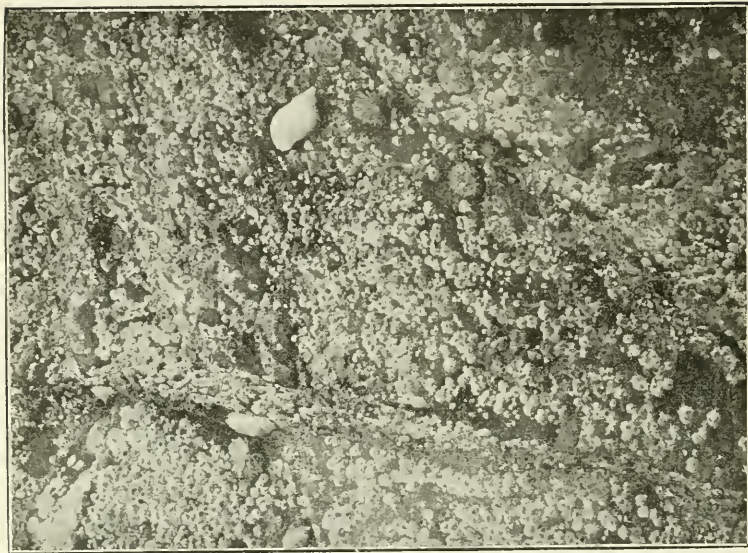
"During the past year I have continued the observations on the habits of *Owenia filiformis*, to which reference was made in the last Report, and I am now working at one or two points which still remain unsettled. In due course I hope to publish a full account, but mean-

time it may perhaps be of interest to state that, by establishing a colony of these annelids in my aquarium, I have been enabled to ascertain their method of reproduction, and to obtain the larval form. This proves to be *Mitraria*, the parentage of which was, I believe, previously unknown."

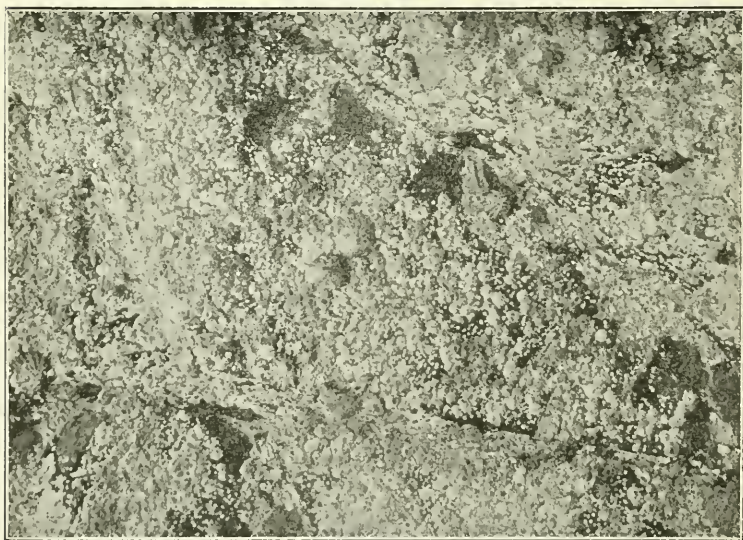
The Rev. T. S. LEA has continued his interesting work on the preparation of photographic records of the habitats and appearance of the littoral plants and animals under natural conditions, either when exposed at low tide or when actually under water. He has produced a most beautiful series of plates showing sea-anemones expanded in shore pools, in some cases catching and swallowing food. Last year Mr. Lea photographed (half-plate size) a marked area of rock covered with adhering animals. This year he has taken the same area, on the same scale. and finds (see fig. 4) that the population has changed almost entirely. All last year's limpets are gone, leaving their scars on the rock; a few of the barnacles seem to be the same individuals. Many thousands of new animals have appeared.

Miss L. R. THORNELY has found on material from Port Erin the following interesting Polyzoa new to our district:—*Mucronella peachii*, var. *labiosa*, previously known from Belfast and Guernsey; and *Mucronella abyssicola*, on a shell, previously known only from Shetland.

Dr. G. W. Chaster informs me that from material dredged in our district by the Fisheries steamer he has obtained the mollusca *Eulima intermedia* (alive and very



June, 1897.



June, 1898.

Fig. 4. Vertical rock-face, Spaldrick Bay, Port Erin, about 6 feet above low water mark. [From photos by Rev. T. S. Lea.]

fine) and *Neolepton obliquatum*, the latter a species which he added to the British fauna from Irish dredgings.

It will be remembered that in our Sixth Annual Report (December, 1892), I gave an account of the colour varieties of the little shore prawn, *Hippolyte* (or *Virbius*) *varians*, and of their "protective" nature, as found on different kinds of sea bottoms at Port Erin. A coloured plate (Pl. VI.) showed the green form on the green plant *Zostera*; a red form on the sea-weeds *Delesseria* and *Rhodymenia*; and a dark olive brown form on the bushes of the brown Alga, *Halidrys siliquosa*. Four possible explanations of the facts were given, and it was stated that an experimental enquiry into the matter was in progress.

The following year, in the Seventh Report (1893, p. 35), the results of the experiments, so far as then obtained, were given, leading to the conclusion "that the adult animal *can* change its colouring very thoroughly, although not in a very short space of time." A short description of the conditions of the differently coloured chromatophores or pigment cells of the skin during these changes was given, and their microscopic characters briefly discussed. It was stated "it would be interesting to determine whether . . . the modification of the chromatophores is due to nerve action and is dependent upon sight, or is the result of the direct action of light upon the integument," but no further experiments bearing upon this point were then made.

During the following year the experiments were repeated at Port Erin, with practically the same results. Glass jars, painted on one side, or covered with coloured papers, as well as those containing coloured weeds, were used; and the prawns, while changing colour, were occasionally examined under the microscope, and some coloured drawings were made of the elaborately branched chromato-

phores, showing the distribution of the blue, yellow, red, brown, and chocolate pigment. The whole subject, so far as then known, was discussed in a lecture at Port Erin, to the Isle of Man Natural History Society, in the summer of 1894, and a passing reference to it was made in the Tenth Annual Report, in connection with other cases of colour change, such as those of some fishes. There I left the matter, and I am glad to say that Mr. James Hornell, in Jersey, and Messrs. F. W. Gamble and F. W. Keeble, in our own district, have now taken up the investigation, with the intention of carrying it further.

Messrs. GAMBLE and KEEBLE, both Demonstrators of Biology in the Owens College, have been making a number of interesting observations and experiments in regard to the physiology of the colour changes of *Hippolyte* and other prawns during this past summer. Most of their work has been carried out at the Piel Sea-Fish Hatchery, but they have in part made use of specimens obtained at Port Erin. Their results are not yet ready for publication, but I may remark that the chief novelty in their methods is the use of water-tight glass chambers, through which fresh aerated sea-water can constantly pass, and in which the prawns can be kept under constant observation while different colours of light are applied. A fuller account of this method, by Messrs. Gamble and Keeble, will be given in the forthcoming Annual Report to the Lancashire Sea-Fisheries Committee.

Professors BOYCE and HERDMAN, with the help of Dr. KOHN, have continued during the year their work on Oysters and Disease, and presented their third, and final, report upon the subject to Section D of the British Association at the Bristol meeting in September. Amongst the conclusions at which they have arrived may be quoted the following :—

"1. There are several distinct kinds of greenness in oysters. Some of these, such as the green Marennes oysters and those of some rivers on the Essex coast, are healthy; while others, such as some Falmouth oysters containing copper, and some American oysters re-bedded on our coast, and which have the pale green leucocytosis we described in the last report, are not in a healthy state.

"2. Some forms of greenness (*e.g.*, the leucocytosis) are certainly associated with the presence of a greatly-increased amount of copper in the oyster, while other forms of greenness (*e.g.*, the Marennes) have no connection with copper, but depend upon the presence of a special pigment Marennin, which may be associated with a certain amount of iron.

"3. We see no reason to think that the iron in the latter case is taken in through the surface epithelium of the gills and palps; but regard it, like the rest of the iron in the body, as a product of ordinary digestion and absorption in the alimentary canal and liver.

"4. We do not find that there is any excessive amount of iron in the green Marennes oyster compared with the colourless oyster; nor do the green parts (gills, palps, &c.) of the Marennes oyster contain either absolutely or relatively to the colourless parts (mantle, &c.) more iron than colourless oysters. We therefore conclude that there is no connection between the green colour of the 'Huitres de Marennes' and the iron they may contain.

"5. On the other hand, we do find by quantitative analysis that there is more copper in the green American oyster than in the colourless one; and more proportionately in the greener parts than in those that are less green. We therefore conclude that their green colour is due to copper. We also find a greater quantity of iron in these green American oysters than in the colourless; but this excess

is, proportionately, considerably less than that of the copper.

“6. In the Falmouth oysters containing an excessive amount of copper, we find that much of the copper is certainly mechanically attached to the surface of the body, and is in a form insoluble in water, probably as a basic carbonate. In addition to this, however, the Falmouth oyster may contain a much larger amount of copper in its tissues than does the normal colourless oyster. In these Falmouth oysters the cause of the green colour may be the same as in the green American oysters.

“7. The Colon group of bacilli is frequently found in shellfish, as sold in towns, and especially in the oyster; but we have no evidence that it occurs in Mollusca living in pure sea-water. The natural inference that the presence of the Colon bacillus invariably indicates sewage contamination must, however, not be considered established without further investigation.

“8. The Colon group may be separated into two divisions—(1) those giving the typical reactions of the Colon bacillus, and (2) those giving corresponding negative reactions, and so approaching the typhoid type; but in no case was an organism giving all the reactions of the *B. typhosus* isolated. It ought to be remembered, however, that our samples of oysters, although of various kinds and from different sources, were in no case, so far as we are aware, derived from a bed known to be contaminated or suspected of typhoid.

“9. Consequently, as the result of our investigations, and the consideration of much evidence, both from the oysters growers' and the public health officers' point of view, we beg to recommend:—

“(a) That the necessary steps should be taken to induce the oyster trade to remove any possible

suspicion of sewage contamination from the beds and layings from which oysters are supplied to the market. This could obviously be effected in one of two ways, either (1) by restrictive legislation and the licensing of beds only after due inspection by the officials of a Government department, or (2) by the formation of an association amongst the oyster-growers and dealers themselves, which should provide for the due periodic examination of the grounds, stores and stock, by independent properly-qualified inspectors. Scientific assistance and advice given by such independent inspectors would go far to improve the condition of the oyster beds and layings, to re-assure the public, and to elevate the oyster industry to the important position which it deserves to occupy.

“(b) Oysters imported from abroad (Holland, France, or America) should be consigned to a member of the ‘Oyster Association,’ who should be compelled by the regulations to have his foreign oysters as carefully inspected and certificated as those from his home layings. A large proportion of the imported oysters are, however, deposited in our waters for such a period before going to market that the fact of their having originally come from abroad may be ignored. If this period of quarantine were imposed upon all foreign oysters a great part of the difficulty as to inspection and certification would be removed.

“(c) The grounds from which mussels, cockles and periwinkles are gathered should be periodically examined by scientific inspectors in the same manner as the oyster beds. The duty of providing for this inspection might well, we should suggest, be assumed by the various Sea-Fisheries Committees around the coast.”

MR. A. R. JACKSON, B.Sc., has continued his work on the Spiders of the neighbourhood of Port Erin, and has now drawn up a list of species which has been communicated to the Biological Society.

MR. ANDREW SCOTT, working chiefly at Piel Island, has made some interesting observations upon the food of young fishes. He finds that young Mullet up to an inch and a little more in length are still feeding entirely upon Diatoms (chiefly *Navicula*). At a length of one-and-a-half inches they feed on both Diatoms and Copepoda (*Tachidius*). Young Herring up to three inches long were found feeding on *Mysis*.

MR. F. J. COLE has continued throughout the year his preparation of material for his joint research with Prof. Herdman on the process of budding and the formation of colonies in compound Ascidians. He has visited Port Erin about four times during 1898 for the purpose of collecting and preserving old and young colonies of the species commonly known as *Amaroucium argus*, which, however, is seen by its anatomical character to belong to the genus *Morchellium*. Mr. Cole and Prof. Herdman have also kept various kinds of compound Ascidians alive under observation in the tanks, so as to record the mode of growth and the positions of the new buds in the colony. Before regarding the collection of material as complete, it has been considered advisable to examine colonies at different times of the year so that no stage of importance might be omitted. Colonies of Ascidians have therefore been collected from month to month from Easter, 1897, and this will be continued until next April. Owing to the difficulty experienced in satisfactorily staining the preparations, the microscopic part of the work is somewhat laborious and takes considerable time. Any detailed statement of results of work would, at the present stage

of the enquiry, be premature, and perhaps lacking in accuracy, but it may be remarked that what is seen in the first series of sections of the young stages of buds is more in accord with the conclusions of Ritter and of Lefevre than of other investigators.

EXTENSION OF THE WORK.

THERE are several matters, in addition to the routine work of the Station, which call for special attention this year.

One of these is the necessity for further exploration in the North Atlantic. Attention has repeatedly been drawn of late years to the importance, both from the purely scientific and the industrial points of view, of the problems involved. The Scandinavians (Petterssen, Ekman, Hjort, and others) have succeeded in unravelling some of the interlacing belts of water from Arctic, Baltic, North Sea, and Atlantic sources which sweep past their coast, and affect the movements of migratory fish. It is only by such work that we can hope to explain rationally the mysterious movements of the Herring—perhaps the most important food fish on our coast.

It was formerly supposed* that when the Herrings left our shores in autumn they retired to the far north, and next season started from the Arctic regions on their annual migration, led by one large old fish—the “King of the Herrings.” We now believe that breeding and feeding are the two impulses that govern the movements of a fish. The Herring comes into shallow water on our coast to spawn, and when it migrates in search of food from the Atlantic to the North Sea, or from our West Coast out into deep water, we have reason to believe that it is following those minute organisms which

* *E.g.*, see Pennants' British Zoology, and article Ichthyology in *Ency. Brit.* for 1857.

form the plankton carried along in particular currents of water, characterised by the temperature, the salinity, and the microscopic fauna. It is possible by these characters to recognise the currents, to trace their variations from year to year, and so to some extent to determine and predict the movements of the shoals of fish. We owe this view chiefly to Professor G. O. Sars, of Christiania. It is, then, to the physical conditions and the biological contents of the water that the movements of the Herring are due, and these are matters within the scope of man's investigation, but outside his power to regulate by local bye-laws, imperial legislation, or even international treaty. This should be recognised by the fishermen and by Sea-Fishery authorities.

It follows, then, that one of the most important things the Biologist can do to add to our knowledge of life in the sea is to make a survey of the microscopic floating and drifting life of the sea, and its relation on the one hand to the physical conditions at the time (especially the temperature and salinity of the water), and on the other to the food materials found in the stomachs of the fish.

The "pump plankton" method, which I described fully before this Society last session, might do much if systematically worked, but it seems difficult to induce anyone on a ship, except a naturalist, to undertake such work, and, moreover, the organisms collected may, unless great care be taken, suffer so much damage in the process, as to be difficult of identification. How, then, are we to sample the plankton of our oceans? The attempt has been made lately to arrange for the stoppage of a steamer at certain fixed points in the ocean long enough to permit of surface and deep-sea gatherings being taken. This method is difficult to arrange, liable to failure, and very expensive considering the very small number of observa-

tions that could be taken—such as eight in a proposed traverse from England to the West Indies.

A much more satisfactory plan, from the scientific point of view, would be to have a series of special cruises, in a vessel of the type of a fisheries steamer, a steam trawler, or a steam yacht able to keep at sea, carrying lines of closely-placed observations across those areas that influence our British Marine Fauna. I would suggest:—

1. A line from Land's End to Porto Rico and Jamaica in the West Indies crossing Rennel's Current, and the mid-Atlantic south of the Gulf Stream area, and tracing back those elements of our floating fauna that we owe to the S.W. Atlantic drift towards their tropical source.

2. A line from Ushant to Iceland, so as to cross the entrance to the English Channel and the drift of the Atlantic organisms on to the west coasts of Ireland and Scotland, and then across the entrance to the Arctic Ocean and North Sea.

3. A line from the Shetlands to the southern end of Greenland, along lat. 60° N., so as to intercept any Arctic flow which brings down the northern forms found in our fauna.

The British Islands occupy a central and commanding position, touching, as Prof. Edward Forbes pointed out long ago, upon the Arctic and Scandinavian faunas to the North, and the Germanic, South European, and Atlantic faunas to the south.

It would also be of considerable scientific interest—although having no bearing so far as can be seen at present upon practical fishery questions—to explore more systematically the seas to the north of Iceland and Norway as far north as dredging and tow-netting are practicable. Sir John Murray, it is well known, has recently revived an old idea that the faunas of the two poles are closely

similar. In opposition to this "bipolar hypothesis," I pointed out last session that in the Tunicata at least there was no special resemblance between the far northern and far southern species, and that, on the other hand, there was a marked similarity between a series of forms from the North Pacific and those from the North Atlantic. Sir John Murray answers me, in a letter on the subject, "I think your remarks quite just. I expect many cases of north and south distribution will be knocked on the head by further discoveries, and that many cases of bipolar distribution not yet evident will be brought to light." Well, we want now to determine how far that is the case. We both agree that what is needed is further facts—more investigation.

There is every prospect that the Antarctic Seas will be fully explored. Several expeditions—Borchgrevink's and others—are there or will be soon, still others are in prospect. The Tunicate fauna of Australian seas is fully as well-known as that of Europe, the marine fauna round Kerguelen Island, thanks to the "Challenger" explorations and Sir John Murray's writings, is better known than that of Iceland, whilst of most of the inhabitants of the seas around Spitzbergen we are practically ignorant.

Moreover, Nansen has opened up a new problem in northern marine exploration. He has shown that a deep sea basin occupies a part at least of the polar area. Where does that basin begin, and how far does it extend? How does it end towards Norway, Iceland, and Greenland? The sea immediately to the north and west of Norway is shallow, running out gradually to a depth of about 200 fathoms, and then, according to Mohn, descending steeply to the bed of the deeper ocean, which reaches a depth of 2000 fathoms or more. We do not yet know the limits nor the inhabitants of that deep basin. In advocating

Antarctic expeditions we must not forget how much still remains to be done within the Arctic circle.

All this may seem to have little connection with our L.M.B.C. work, but it is the natural extension and outcome of what we have been doing. As the problems develop we must widen our area. We commenced twelve years ago with Hilbre Island and Liverpool Bay—our work has now for several years extended all over the Irish Sea. This means practically the western fauna of Britain influenced by the Atlantic drift from the south-west and the Arctic currents from the north. Whether the relation of our north-western European fauna to that of north-western America depends upon a common circum-polar fauna as I have suggested, and whether our thorough comprehension of the Arctic fauna is bound up, as Murray thinks, with Antarctic explorations, are questions still to be answered; but this much is clear, that one enquiry in the distribution of animals leads to another, and the different faunas are like links in a chain or strands in a net—the mesh-work of life extending over the globe—just what we should expect from the consideration that all living things spread from a centre, that multiplication, struggle for existence, migration, survival of the fittest, and varying degrees of isolation have produced the difference we now find between the present inhabitants of the different regions.

I should like, then, to push our L.M.B.C. investigations further afield—out into the North Atlantic, across to the West Indies, up into the Northern Seas. And all that is wanting is a fund to meet the necessary expenses. We can find the scientific men willing to give the time and do the work. What we want is a yacht-owner willing to use his vessel, fitted up with the necessary equipment,

for scientific exploration of an interesting and important nature, such as the Prince of Monaco is now doing.

There are two practices in American universities which excite the envy of professors in this country. One is the "sabbatical year"—the one year in every seven given for purposes of travel, study, and investigation. The other is the frequent endowment of an expedition—or equipment of an exploring party—by an individual man or woman who is interested in the subject, and can give a special fund for such a purpose. The Columbia University in New York, the Johns Hopkins University in Baltimore, Yale College in Newhaven, and Harvard at Cambridge, have all benefitted immensely in the past by such exploring expeditions. Nearly every year of late has seen one or more of such, due to private generosity, in the field; and the work they have done has both added to general scientific knowledge, and has also enriched with collections the laboratories and museums of the college to which the expedition belonged.

It may be that the reason why this excellent system of exploring parties from the universities has attained such slight development in our country is that our professors are not so enterprising in making known the wants of science—not so importunate in their demands upon the community in which they live—as their transatlantic brethren. It may be that some think that in this long-settled country there is nothing left to explore—no greater mistake could be made. I am sure that the geologist and the archæologist could point to innumerable problems still to be attacked on land, while our seas are far more vast, and comparatively far less known than the shores. I am sure that many marine zoologists could be usefully employed during their vacation for the next ten years in exploring such regions as I have

indicated above. While, if we pass from questions of distribution to those of structure and life-histories, even the best-known regions afford abundant opportunity for research to all who enter the field.

Marine Biology has this peculiar advantage, that invoking as it does the aid of several neighbouring sciences, such as Geology, Geography, and Physiology, it is able in its turn to throw light upon these subjects, and it bristles with problems of that interesting and intricate nature that characterises the borderland between two or more sciences.

SOME RECENT WORK.

As a contribution to the borderland between our subject and Geology, Mr. Lomas and I have, during the past year, made a careful examination of all our dredged deposits from the floor of the Irish Sea, and our results have appeared in the last volume of "Proceedings" of the Liverpool Geological Society. Amongst our results we may note that we have shown how the material now covering the floor of the Irish Sea have been the result (1) of the denudation of the coasts, (2) of the redistribution of the older deposits under the sea, (3) of vital agencies—the remains of animals and plants living in the sea. We give a revised classification of such deposits, and a detailed description of all the samples we have obtained.

As a problem on the boundary between Biology and Geography (viz., the currents of the sea), and as having, at the same time, an important practical application to the sea-fisheries, may be cited our investigation of the circulation of water in the Irish Sea by means of "drift-bottles." Our records of those bottles that have been found and returned to us show pretty conclusively that there is, in addition to both north and south in-flowing and out-going tidal currents, a slow drift to the north,

which would carry, for example, floating objects, such as fish eggs and embryos, gradually further and further to the north. So that, from the spawning grounds south of the Isle of Man, they may be carried towards and along the Lancashire coast and from say the "Hole" and other parts of the central area, to Cumberland and the Solway Firth.

As another research intimately bound up with the local fisheries, I would allude to our plankton investigations. During the past year surface gatherings have been sent from various localities with more or less regularity. The result of the examination of these, on the whole, confirms very well the general conclusions we drew in the last Report as to the succession of forms throughout the year.

We find very considerable difference between gatherings from different localities; for example, whereas the tow-nettings from Port Erin are clear and clean and support an abundant assemblage of minute animals, those taken about the same time off Peel, in the Barrow Channel, contain much vegetable *débris*, mud, &c., due to the influence of fresh-water and the washings of the land. The true open sea at Port Erin and the absence of any body of fresh-water, and of any mud flats, ensure the presence of a much larger number of Copepoda, Dinoflagellata, and other characteristic pelagic organisms than are elsewhere. We have also noticed that the various constituents of the surface life—both larval and adult—appear earlier at Port Erin than on the Lancashire coast.

THE MANX SEA-FISHERIES COMMISSION.

The report which recently appeared containing the recommendations of the Manx Industries Commission, so far as they relate to sea-fisheries, includes an important paragraph in which it is suggested that the Hatchery

which is contemplated be established in connection with our Biological Station at Port Erin. The possibility of some such arrangement being proposed, caused the Committee to consider carefully the ground in the neighbourhood of the Station with the view of determining how far they could offer accommodation for economic work, and what additional building and plant would be required before they could undertake sea-fish hatching on anything beyond an experimental scale. The chief requirements for such a purpose are as follows:—

1. An extension of the Aquarium house, to hold the hatching boxes.
2. A small boat jetty.
3. A concrete pond on the shore.
4. A circulation of sea-water.

All of these are merely a matter of expense. They can readily be provided if a grant be given for the purpose. The hatching-house will cost about £80, the jetty £70, and the pond £80; say, including the fittings of the hatchery, £250 in all.

As to a constant flow, or circulation, of sea-water, there is no gas supply in Port Erin, and if worked by a steam engine a very considerable expenditure and the services of an engineer would be required. A much more economical plan, and one that would probably be quite sufficient for the wants of the institution, would be to pump from the sea-well to the uppermost tank by means of a small wind-mill, as is done in some of the Biological Stations abroad. This would be comparatively inexpensive, and would not require material addition to the service of the institution; our present Curator with the assistance of a strong lad, and possibly a second fisher lad during the hatching season, would be able to undertake the work.

L.M.B.C. PUBLICATIONS.

During the past year the following papers dealing with L.M.B.C. work have been published :—

1. The Eleventh Annual Report (Trans. Biol. Soc., vol. XII., p. 91).

2. The Sea-Fisheries Laboratory Report for 1897 (Trans. Biol. Soc., vol. XII., p. 176).

3. Note on a Tetramerous Specimen of *Echinus esculentus*. By H. C. Chadwick (Trans. Biol. Soc., vol. XII., p. 288).

4. Actinological Studies, I.—The Mesenteries and Œsophageal Grooves of *Actinia equina*. By J. A. Clubb, M.Sc. (Trans. Biol. Soc., vol. XII., p. 300).

5. Report on Oysters and Disease, by Prof. Boyce and Prof. Herdman (Brit. Assoc. Rep.), with an Appendix on Iron and Copper in Oysters, by Dr. Kohn.

6. The Deposits on the Floor of the Irish Sea. By Prof. Herdman and Mr. Lomas (Proc. Liverpool Geol. Soc., vol. VIII., p. 205).

It is hoped that volume V. of the "Fauna and Flora," containing reprints of these and all other papers on our local work published since the appearance of vol. IV. (in 1895) will be ready to issue during the present winter.

I am inclined to think that the time has now arrived when it may be the duty of the Committee to issue a new form of publication. Our work hitherto, during the last 12 years, has been largely faunistic and speciographic. The work of necessity must be so at first when opening up a new district. Some of our workers have published papers on morphological points, or observations on life histories and habits; but the majority of the papers in our volumes on the Fauna and Flora of Liverpool Bay have been, as was intended, occupied with the names and characteristics and distribution of the many different

kinds of plants and animals in our marine district. And this Faunistic work will still go on. It is far from finished, and I hope we shall still add greatly to our records of the Fauna and Flora; but in addition it might be useful to produce a series of

L.M.B.C. MEMOIRS.

What I now propose is that each of our specialists should carefully prepare a full account, illustrated by all the necessary figures, of one or two common but important animals belonging to the group upon which he is an authority; and that these detailed and fully illustrated accounts should be issued as a series of L.M.B.C. Memoirs — obtainable at first separately, memoir by memoir as they appear, and then later bound up, say 5 or 6 together, in convenient volumes. I believe that such a series of special studies, written by those who are thoroughly familiar with the forms of which they treat, will be of great value to students in our laboratories and in Biological Stations, and will be welcomed by many working at marine biology. It is proposed that the forms selected should, as far as possible, be common L.M.B.C. (Irish Sea) animals of which no adequate account already exists in any text book. Probably all the members of our band of specialists will be willing to help in this work. The following have already promised their services, and will probably treat of the species placed opposite their names:—

Professor Harvey Gibson	<i>Zostera marina.</i>
Mr. C. E. Jones ...	... <i>Halidrys siliquosa.</i>
Professor Weiss ...	... Typical Diatoms (<i>Biddulphia</i> , <i>Chaetoceros</i> , <i>Schizonema</i> , and <i>Licmophora</i>).

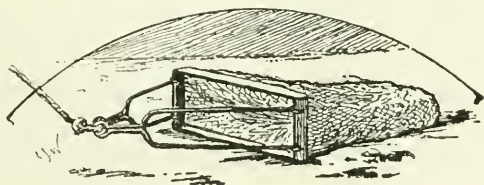
Dr. O. V. Darbishire	...	A Red Sea-weed.
Mr. F. J. Cole	...	The Plaice.
Professor Herdman	...	<i>Ascidia</i> and <i>Botrylloides</i> .
Mr. W. E. Hoyle	...	A Cuttle-fish (<i>Eledone</i>).
Mr. J. Johnstone...	...	The Cockle.
Mr. Andrew Scott	...	An Ostracod and an Epizoon.
Mr. I. C. Thompson	...	<i>Calanus finmarchicus</i> .
Mr. H. C. Chadwick	...	<i>Echinus</i> , the Sea-urchin.
Mr. J. A. Clubb	...	An Actinian.
Miss L. R. Thornely	...	A Polyzoon Colony.
Dr. Hanitsch	...	A Calcareous Sponge.

Now, all these memoirs will require to be carefully illustrated with well-drawn plates, and fortunately the Committee have at their disposal a small annual sum of money (the British Association—1896—fund) which it was proposed from the first should be devoted to just such a purpose as this. That, however, leaves the printing of the memoirs still unprovided for, and with the Curator's salary and other expenses at Port Erin to meet, it will be quite impossible to spare anything for general funds. A special subscription will have to be raised to defray the expenses of the L.M.B.C. Memoirs.

I should also like to point out that papers on special points in the Zoology of Sea-Animals are being sent by our workers to London Scientific Societies, because we have not the funds to publish them satisfactorily in Liverpool. Mr. Andrew Scott has just finished a beautiful series of water-colour drawings of fish eggs, embryos and larvæ, from his investigations during the year at our Lancashire Fish Hatchery. They will be expensive to reproduce and publish, but it will be very discreditable to Committee, and City, and County, if we allow this excellent local work to be issued under

the auspices of some society in London or Edinburgh. The fact is—and a very important and gratifying fact it must be to our subscribers and supporters who have helped us from year to year—that we have now in connection with our Committee an exceedingly active School of Marine Biology, every worker in which is engaged in some piece of original research. Liverpool is the right and natural place for a School of Marine Biology, and I hope that Liverpool will consider that it is creditable to the city that such local researches should be published by a Liverpool Society. An addition of about £100 a year to our funds is necessary in order to enable us to do justice to the work now being produced by our colleagues and students.

The Biological exploration of Liverpool Bay has all along been intimately connected with University College, and it is to be hoped that when the time comes—and it ought not to be long delayed—for building new biological laboratories, accommodation will be provided within the department for our School of Marine Biology. A museum devoted to exhibiting the products of the local seas, and a laboratory fitted for conducting researches upon marine life, must surely be constituent parts of the University of a great sea-port.



APPENDIX A.

THE LIVERPOOL MARINE BIOLOGY
COMMITTEE (1898).

- R. D. DARBISHIRE, Esq., B.A., F.G.S., Manchester.
PROF. R. J. HARVEY GIBSON, M.A., F.L.S., Liverpool.
HIS EXCELLENCY LORD HENNIKER, Governor of the Isle
of Man.
PROF. W. A. HERDMAN, D.Sc., F.R.S., F.L.S., Liverpool,
Chairman of the L.M.B.C., and Hon. Director of
the Biological Station.
W. E. HOYLE, Esq., M.A., Manchester.
A. LEICESTER, Esq., formerly of Liverpool.
SIR JAMES POOLE, J.P., Liverpool.
DR. ISAAC ROBERTS, F.R.S., formerly of Liverpool.
I. C. THOMPSON, Esq., F.L.S., Liverpool, Hon. Treasurer.
A. O. WALKER, Esq., F.L.S., J.P., Colwyn Bay.
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CONSTITUTION OF THE L.M.B.C.

(Established March, 1885.)

I.—The OBJECT of the L.M.B.C. is to investigate the Marine Fauna and Flora (and any related subjects such as submarine geology and the physical condition of the water) of Liverpool Bay and the neighbouring parts of the Irish Sea; and if practicable to establish and maintain a Biological Station on some convenient part of the coast.

II.—The COMMITTEE shall consist of not more than 12 and not less than 10 members, of whom 3 shall form a quorum; and a meeting shall be called at least once a year for the purpose of arranging the Annual Report, passing the Treasurer's accounts, and transacting any other necessary business.

III.—During the year the AFFAIRS of the Committee shall be conducted by an HON. DIRECTOR, who shall be Chairman of the Committee, and an HON. TREASURER, both of whom shall be appointed at the Annual Meeting and shall be eligible for re-election.

IV.—Any VACANCIES on the Committee, caused by death or resignation, shall be filled by the election, at the Annual Meeting, of those who, by their work on the Marine Biology of the district, or by their sympathy with science, seem best fitted to help in advancing the work of the Committee.

V.—The EXPENSES of the investigations, of the publication of results, and of the maintenance of the Biological Station shall be defrayed by the Committee, who for this purpose shall ask for subscriptions or donations from the public, and for grants from scientific funds.

VI.—The BIOLOGICAL STATION shall be used primarily for the Exploring work of the Committee, and the SPECIMENS collected shall, so far as is necessary, be placed in the first instance at the disposal of the members of the Committee and other specialists who are reporting upon groups of organisms; work places in the Biological Station may, however, be rented by the week, month, or year to students and others, and duplicate specimens which, in the opinion of the Committee, can be spared may be sold to museums and laboratories.

LIVERPOOL MARINE BIOLOGICAL STATION at PORT ERIN.

LABORATORY REGULATIONS.

I.—This Biological Station is under the control of the Liverpool Marine Biological Committee, the executive of which consists of the Hon. Director (Prof. Herdman, F.R.S.) and the Hon. Treasurer (Mr. I. C. Thompson, F.L.S.).

II.—In the absence of the Director, and of all other members of the Committee, the Station is under the temporary control of the Resident Curator or Laboratory Assistant, who will keep the keys, and will decide, in the event of any difficulty, which places are to be occupied by workers, and how the tanks, boat, collecting apparatus, &c., are to be employed.

III.—The Resident Curator will be ready at all reasonable hours and within reasonable limits to give assistance to workers at the Station, and to do his best to supply them with material for their investigations.

IV.—Visitors will be admitted, on payment of a small specified charge, to see the Aquarium and the Station, so long as it is found not to interfere with the scientific work. Occasional lectures are given by members of the Committee.

V.—Those who are entitled to work in the Station, when there is room, and after formal application to the Director, are:—(1) Annual Subscribers of one guinea or upwards to the funds (each guinea subscribed entitling to the use of a work place for four weeks), and (2) others who are not annual subscribers, but who pay the Treasurer 10s. per week for the accommodation and privileges. Institutions, such as Colleges and Museums, may become

subscribers in order that a work place may be at the disposal of their staff for a certain period annually; a subscription of two guineas will secure a work place for six weeks in the year, a subscription of five guineas for four months, and a subscription of £10 for the whole year.

VI.—Each worker* is entitled to a work place opposite a window in the Laboratory, and may make use of the microscopes, reagents, and other apparatus, and of the boats, dredges, tow-nets, &c., so far as is compatible with the claims of other workers and with the routine work of the Station.

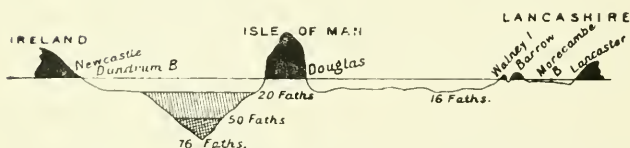
VII.—Each worker will be allowed to use one pint of methylated spirit per week, free. Any further amount required must be paid for. All dishes, jars, bottles, tubes, and other glass may be used freely, but must not be taken away from the Laboratory. Workers desirous of making, preserving, and taking away collections of marine animals and plants, can make special arrangements with the Director or Treasurer in regard to bottles and preservatives. Although workers in the Station are free to make their own collections at Port Erin, it must be clearly understood that (as in other Biological Stations) no specimens must be taken for such purposes from the Laboratory stock, nor from the Aquarium tanks, nor from the steam-boat dredging expeditions, as these specimens are the property of the Committee. The specimens in the Laboratory stock are preserved for sale, the animals in the tanks are for the instruction of visitors to the Aquarium, and as all the expenses of steam-boat dredging expeditions are defrayed by the Committee the specimens obtained on these occasions must be retained by the

* Workers at the Station can always find comfortable and convenient quarters at the closely adjacent Bellevue Hotel; but lodgings can readily be had by those who prefer them.

Committee (*a*) for the use of the specialists working at the Fauna of Liverpool Bay, (*b*) to replenish the tanks, and (*c*) to add to the stock of duplicate animals for sale from the Laboratory.

VIII.—Each worker at the Station is expected to lay a paper on some of his results—or at least a short report upon his work—before the Biological Society of Liverpool during the current or the following session.

IX.—All subscriptions, payments, and other communications relating to finance, should be sent to the Hon. Treasurer, Mr. I. C. Thompson, F.L.S., 53, Croxteth Road, Liverpool. Applications for permission to work at the Station, or for specimens, or any communication in regard to the scientific work should be made to Professor Herdman, F.R.S., University College, Liverpool.



Diagrammatic Section across the Irish Sea.

APPENDIX B.

HON. TREASURER'S STATEMENT.

From the balance sheet appended it will be seen that the year ends with a small debit balance, in spite of the fact that all due economy has been observed, consistent with efficiency.

The British Association (1896) fund has, to a considerable extent, enabled the Committee to meet the necessary extra expense involved in securing the services of a competent Resident Curator at the Port Erin Station, which has already proved of great benefit to workers.

Increased workroom accommodation has also been added at the Station during the year, at a cost of about £14.

As pointed out by the Director in his Report (p. 55), an additional income of about £100 per annum could be most advantageously utilized in publishing well-illustrated papers and memoirs, embodying the results of local biological investigations such as, for want of funds, have unfortunately, in some cases, been sent, in the past, to other societies outside Liverpool.

The Hon. Treasurer, on behalf of the Committee, will be glad to receive the names of new subscribers, with the view of remedying this deficiency, and of further adding very materially to the already excellent work achieved under the auspices of the L.M.B.C. since its foundation, twelve years ago.

SUBSCRIPTIONS and DONATIONS.

	Subscriptions.			Donations.		
	£	s.	d.	£	s.	d.
Ayre, John W., Ripponden, Halifax ...	1	1	0	—		
Bateson, Alfred, Harrop-road Bowdon ...	1	1	0	—		
Beaumont, W. I., Cambridge ...	1	1	0	—		
Bickerton, Dr., 88, Rodney-street ...	1	1	0	—		
Bickersteth, Dr., 2, Rodney-st. ...	2	2	0	—		
Brown, Prof. J. Campbell, Univ. Coll. ...	1	1	0	—		
Browne, Edward T., B.A., 141, Uxbridge- road, Shepherd's Bush, London ...	1	1	0	—		
Brunner, Sir J. T., Bart., M.P., Druids Cross ...	5	0	0	—		
Boyce, Prof., University College ...	1	1	0	—		
Caton, Dr., 86, Rodney-street ...	—			1	1	0
Clague, Dr., Castletown, Isle of Man ...	1	1	0	—		
Clague, Thomas, Bellevue Hotel, Port Erin	1	1	0	—		
Cole, F. J., (research table) ...	1	1	0	—		
Coombe, John N., 4, Paradise-sq., Sheffield	1	1	0	—		
Comber, Thomas, J.P., Leighton, Parkgate	1	1	0	—		
Crellin, John C., J.P., Ballachurry, An- dreas, Isle of Man ...	0	10	6	—		
Crossland, Cyril, Clare College, Cambridge	1	0	0			
Gair, H. W., Smithdown-rd., Wavertree	2	2	0	—		
Gamble, Col. C.B., Windlehurst, St. Helens	2	0	0	—		
Gamble, F.W., Owens College, Manchester	1	1	0	—		
Gaskell, Frank, Woolton Wood ...	1	1	0	—		
Gaskell, Holbrook, J.P., Woolton Wood	1	1	0	—		
Gibson, Prof. R. J. Harvey, 5, Adelaide- terrace, Waterloo ...	1	1	0	—		
Glynn, Dr., 62, Rodney-street ...	2	2	0	—		
Gotch, Prof., Museum, Oxford ...	1	1	0	—		
Forward ...	£32	13	6	1	1	0

		Subscriptions.			Donations.		
		£	s.	d.	£	s.	d.
Forward ...		32	13	6	1	1	0
Halls, W. J., 35, Lord-street ...	...	1	1	0	—		
Hanitsch, Dr., Museum, Singapore ...	...	1	1	0	—		
Henderson, W. G., Liverpool Union Bank		1	1	0	—		
Herdman, Prof., University College ...	...	2	2	0	—		
Hewitt, David B., J.P., Northwich ...	...	1	1	0	—		
Holland, Walter, Mossley Hill-road ...	...	2	2	0	—		
Holt, Alfred, Crofton, Aigburth ...	...	2	2	0	—		
Holt, Mrs. George, Sudley, Mossley Hill		1	0	0	—		
Hoyle, W. E., Museum, Owens College, Manchester ... ..	...	1	1	0	—		
Isle of Man Natural History and Anti- quarian Society ... ..	...	1	1	0	—		
Jarmay, Gustav, Hartford ... ..	...	1	1	0	—		
Jones, C.W., J.P., Field House, Wavertree		1	0	0	—		
Kernode, P. M. C., Hill-side, Ramsey ...	...	1	1	0	—		
Lea, Rev. T. Simcox, 3, Wellington-fields		1	1	0	—		
Leicester, Alfred, Buckhurst Farm, Eden- bridge, Kent ... ..	...	1	1	0	—		
Macfie, Robert, Airds ... ..	...	1	0	0	—		
Meade-King, H. W., J.P., Sandfield Park		1	1	0	—		
Meade-King, R. R., 4, Oldhall-street ...	...	0	10	0	—		
Melly, W. R., 90, Chatham-street ...	...	1	1	0	—		
Monks, F. W., Brooklands, Warrington		1	1	0	—		
Mundy, Randal, Manchester ... ..	...	0	10	0	—		
Muspratt, E. K., Seaforth Hall ... ..	...	5	0	0	—		
Newton, John, M.R.C.S., 44, Rodney-st.		0	10	6	—		
O'Kell, Robert, B.A., Sutton, Douglas ...	...	1	1	0	—		
Paterson, Prof., University College ...	...	1	1	0	—		
Poole, Sir James, Tower Buildings ...	...	2	2	0	—		
Rathbone, Mrs. Theo., Backwood, Neston		1	1	0	—		
Rathbone, Miss May, Backwood, Neston		1	1	0	—		
Forward ...		£68	9	0	1	1	0

			Subscriptions.			Donations.		
			£	s.	d.	£	s.	d.
Forward ...			68	9	0	1	1	0
Rathbone, W., Greenbank, Allerton	...		2	2	0	—		
Roberts, Isaac, F.R.S., Crowborough	...		1	1	0	—		
Shackleford, Rev. L. J., Clitheroe	...		0	10	0	—		
Simpson, J. Hope, Annandale, Aigburth-dr			1	1	0	—		
Smith, A. T., junr., 24, King-street	...		1	1	0	—		
Talbot, Rev. T. U., 4, Osborne-terrace,								
Douglas, Isle of Man	...	...	1	0	0	—		
Thompson, Isaac C., 53, Croxteth-road			2	2	0	—		
Thornely, James (the late), Baycliff,								
Woolton	...	...	1	1	0	—		
Thornely, The Misses, Baycliff, Woolton			1	1	0	—		
Toll, J. M., Kirby Park, Kirby	...	...	1	1	0	—		
Torrance, Gilbert, North Quay, Douglas			1	1	0	—		
Walker, A. O., Nant-y-glyn, Colwyn Bay			3	3	0	—		
Walker, Horace, South Lodge, Princes-pk.			1	1	0	—		
Walters, Rev. Frank, B.A., King William								
College, Isle of Man	...	...	1	1	0	—		
Watson, A. T., Tapton-crescent, Sheffield			1	1	0	—		
Weiss, Prof. F. E., Owen's College, Man'tr.			1	1	0	—		
Westminster, Duke of, Eaton Hall	...		5	0	0	—		
Wiglesworth, Dr., Rainhill	1	1	0	—		
Yates, Harry, 75, Shude-hill, Manchester			1	0	0	—		
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SUBSCRIPTIONS FOR THE HIRE OF "WORK-TABLES," OCCUPIED
BY COLLEGES, &c.

Owens College, Manchester	£10	0	0
University College, Liverpool	10	0	0
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			£20	0	0
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THE LIVERPOOL MARINE BIOLOGY COMMITTEE.

Dr.

IN ACCOUNT WITH ISAAC C. THOMPSON, HON. TREASURER.

Cr.

1898.		1898.	
	£ s. d.		£ s. d.
To Balance due Treasurer, Dec. 31st, 1897.....	2 15 4	By Subscriptions and Donations actually received.....	87 10 0
" Printing Reports and Engraving Plates	17 11 6	" Amount received from Colleges, &c., for hire of	
" Printing and Stationery	2 7 9	" Work Tables"	20 0 0
" Expenses of Dredging Expeditions	19 3 3	" Dividend, British Workman's Public House Co.,	
" Boat Hire.....	4 2 1	Ltd., Shares	5 18 9
" Books and Apparatus at Port Erin Biological Station	16 7 7	" Sale of Nat. Hist. Specimens	2 4 5
" Postage, Carriage of Specimens, &c.	2 6 4	" Sale of Reports and Volumes of Fauna	3 11 0
" Salaries, Curator and Laboratory boy.....	68 13 4	" Interest on British Association (1896) Fund	32 2 2
" Rent of Port Erin Biological Station	15 0 0	" Bank Interest.....	0 3 5
" Cost of New Workroom.....	14 11 3	" Admissions to Aquarium	6 7 5
" Sundries	1 7 0	" Balance due Treasurer, Dec. 31st, 1898.....	6 8 3
	<u>£164 5 5</u>		<u>£164 5 5</u>
		Endowment Investment Fund :—	
		British Workmans' Public House Co's. shares .....£173 1 0	

ISAAC C. THOMPSON,

HON. TREASURER.

LIVERPOOL, December 31st 1898.

Audited and found correct,

A. T. SMITH, JUNR.

LIST of the ARANEIDA of PORT ERIN and DISTRICT.

By A. R. JACKSON, B.Sc. (VICT.),
Victoria University Scholar in Zoology.

WHILE occupying the University College work-place in the Port Erin Biological Station during the session 1897-98, in addition to my study of marine life, I paid some attention to collecting the spiders of the neighbourhood.

Prof. Herdman suggested that I should follow this up, on a further visit to the station, with the object of completing a list of the Araneida found at Port Erin; and I am now, as the result of my observations, able to record the following 57 species. They were all found within a radius of 1 mile of the Biological Station, except *Amaurobius ferox* and *Epeira quadrata*.

ARANEIDA.

I. DYSDERIDÆ.

Dysdera crocata, rare.

Harpactis hombergii, fairly common.

Segestria senoculata, very common.

II. DRASSIDÆ.

Micaria pulicaria, fairly common.

Prosthesima latreillei, fairly common.

P. pusilla, rare, only two specimens were taken.

Drassus lapidosus, very common.

D. cupreus, very common.

D. troglodytes, fairly common.

Clubiona terrestris, fairly common.

C. reclusa, fairly common.

III. AGELENIDÆ.

Tegenaria derhami, very common.

Textrix denticulata, fairly common.

IV. DICTYNIDÆ.

Amaurobius fenestralis, very common.

A. similis, very common.

A. ferox, very local, found in Ballasalla quarries.

V. THERIDIIDÆ.

Theridion sisypum, common, and only taken in
Colby glen.

Phyllonethis lineata, very common.

Asagena phalerata, one specimen, on the moors.

Ero furcata, only cocoons found.

Pholcomma gibbum, one specimen.

Linyphia triangularis, very common.

L. pusilla, one specimen, on the cliffs.

L. lineata, fairly common.

L. clathrata, fairly common.

Leptyphantes leprosus, very common.

L. minutus, very common.

L. blackwallii, fairly common.

L. tenuis, fairly common.

Bathyphantes concolor, very common.

B. variegatus, fairly common.

Nerienne rubens, fairly common.

N. bipunctata, fairly common.

Erigone atra, very common.

E. dentipalpis, very common.

Pedanostethus lividus, fairly common, in gorse
bushes.

Tiso vagans, rare.

Ceratinella breve, fairly rare.

Peponocranium ludicrum, very common.

Pachygnatha degeeri, common.

VI. EPEIRIDÆ.

Meta menardii, in Bradda mines, very local.

M. merianæ, very common.

M. segmentata, very common.

Zilla x-notatum, very common.

Epeïra umbratica, very common and local, on cliffs.

E. diademata, very common, local.

E. quadrata, very common, and found at Foxdale.

VII. THOMISIDÆ.

Xysticus cristatus, very common everywhere.

VIII. LYCOSIDÆ.

Lycosa ruricola, very common.

L. terricola, very common.

L. pulverulenta, very common.

Pardosa nigriceps, fairly common.

P. pullata, very common.

P. amentata, very common.

P. palustris, very common.

IX. ATTIDÆ.

Epiblemium scenicum, rare, two specimens found on laboratory wall.

Heliophanus cupreus, fairly common.

REPORT on the INVESTIGATIONS carried on in 1898 in connection with the LANCASHIRE SEA-FISHERIES LABORATORY at University College, Liverpool, and the SEA-FISH HATCHERY at Piel, near Barrow.

Drawn up by Professor W. A. HERDMAN, F.R.S., Honorary Director of the Scientific Work; assisted by Mr. ANDREW SCOTT, Resident Fisheries Assistant at Piel, and Mr. JAMES JOHNSTONE, Fisheries Assistant at Liverpool.

With Plates I. and II.

[Read March 17th, 1899.]

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INTRODUCTION.

THIS is the first complete year of Mr. Scott's work at the Piel Hatchery and of Mr. Johnstone's work at the Liverpool Laboratory, and a glance merely at the above table of contents will show the extent and variety of the investigations that have been undertaken.

Mr. Scott's work has been in the main economic—the hatching of eggs of marketable fishes and the improvement of apparatus and fittings so as to carry on such work more efficiently in the future. He has also, however, examined many tow-net gatherings and other samples of the organisms in the waters and on the shores of our district, and has carried out a further series of experi-

ments with large "drift" bottles. These, and also his observations upon young stages of the Eel, are given below in separate sections. In addition to Mr. Scott's own work at Piel we have a first report from Messrs. Gamble and Keeble, Demonstrators of Biology at the Owens College, Manchester, upon the interesting work that they were conducting at Piel during a considerable portion of last summer.

In one of his letters to me at the beginning (June) of the research Mr. Gamble says: "We hope by the end of summer to have some sound experimental evidence of the nature of colour change in *Virbius* and possibly in *Mysis* as well. . . . Our apparatus consists partly of an arrangement for maintaining a constant stream of water through a series of observation vessels and partly of an arrangement by which air is sucked through a second set of vessels. Thus we can determine whether change of air or change of water is the most conducive to health. Then in addition to a dark box we have a series of 'light-filters' by means of which we can obtain the influence of monochromatic light on *Virbius* both in the above-mentioned vessels and under the microscope. . . . For exact physiological work, the sea-water and gas laid on in the Laboratory at Piel are an immense advantage—to say nothing of the excellent accommodation, and from what we managed to do a few weeks ago both Keeble and I hope that before the end of September we may have settled some important questions in connection with the colour-reactions of Crustacea to various stimuli." For further particulars I refer to the authors' report given below (p. 149).

This work has, at present, no obvious connection with economic fishery problems, but it is impossible to foretell, in these days of rapid advance in discovery, and in the

application of science to industries, how soon the results of what now seems an investigation in pure science may turn out to have some important practical bearing. For my part I am of opinion that all knowledge of animal life in our seas is of importance, and will help us to understand the life and ways of fishes.

That a detailed knowledge of the sea and its contents (however minute) must be the basis of fishery practice and regulation is recognised in the following extract from the Memorial in favour of International Oceanographic Exploration sent last April by the Swedish Government to our Foreign Office :—"All fishing in the North Atlantic, and especially the presence of the migratory fishes, depends upon the great currents in the upper layers of the sea, and the variation of the presence in these layers of the food required by the fishes, viz., 'Plankton' or organisms of animal or vegetable origin floating in the water. A knowledge of these currents and of the quality and quantity of food they contain is necessary in order to determine the legislation required for the creation of a rational organisation of the fisheries." Then, again, the migrations of the Cod towards the Lofoten banks and fjords, and of the winter Herring into the Skagerack, seem, according to Otto Pettersson, to be regulated by the impact of cold Arctic and west Atlantic water in winter driving the fishes to those parts of the sea where the conditions are less unfavourable.

It is considerations such as these that lead naturalists to urge that fishery observations and investigations must not be restricted by any territorial or administrative boundaries, but should be extended to off-shore waters, and even the high seas, so as to follow up and unravel the factors that contribute to the distribution of our coast fisheries.

Mr. Ascroft has also stayed some time at the Piel Hatchery, and we include in this Report a short account from him of his observations on the separation of mud from sea-water by shell-fish and on the growth of mud banks upon beds of shell-fish, especially Mussels.

It may be well to note here that the well-equipped biological Laboratory with tank-house at Piel is now open, upon certain conditions, to duly qualified investigators. In addition to the Laboratory accommodation, the building provides dining-room, writing-room or library, and about eight bed-rooms for workers. No charge is made for residence, and meals are provided at a fixed and reasonable rate. The regulations for workers, as approved by the Committee, are appended to this Report.

During the course of his work in hatching Cod, Plaice, and other fish at Piel last spring, Mr. Scott made a number of coloured drawings of the various embryonic and larval stages of our common fishes. We hope that these may be published on a future occasion, when the series is more complete.

Having succeeded so far, and shown that the work can be conducted with the sea-water pumped up at Piel, Mr. Scott is naturally anxious to be supplied with a pond in which to keep spawning fish, and with a proper outfit of hatching boxes, so as to be able to carry on operations on a much larger scale. As Capt. Dannevig in Norway and the Scottish Fishery Board (lately at Dunbar, and for the future at Aberdeen) have adopted a special form of hatching apparatus, in which the little cubical boxes containing the developing eggs are rocked up and down constantly in the water of a larger tank, with, so far as we can ascertain, very good results, it certainly seems desirable that we should try some of these "Dannevig rocking boxes" at Piel, for comparison with the simple

tanks with constant flow of water, which we used last year. Five sets of rocking boxes have, therefore, been ordered from Norway, where they are made under the direction of Capt. Dannevig, and are expected to arrive at Piel in a few days. They will be set up along the east wall of the tank-house, and the plain tanks, which will also be in use this coming season, are now being moved into the adjoining portion of the verandah, which is being enclosed for the purpose so as to form an extension of the tank-house.*

The provision of a satisfactory spawning pond, in which the parent fish can be kept in considerable numbers until they produce their eggs, is a more difficult matter. The Scientific Sub-Committee have had the matter under consideration at several meetings, and I have gone carefully into the question of alternative sites, on the ground, with the Chairman, the Superintendent, Mr. Scott, and the Engineer to the Railway Co. (our landlords at Piel). The difficulty is to get a site which is sufficiently near to the hatchery, sufficiently protected from heavy seas, which can be excavated to a sufficient depth, and which will enable the pond to be constructed at a reasonable cost. A tidal pond, such as that now being constructed at Bay of Nigg, Aberdeen, by the Fishery Board for Scotland, has certain obvious advantages, the chief of which is that no pumping is required, but it is open to the objection that it must of necessity (at Piel) be on the shore, and, therefore, exposed to the seas.

We are trusting for one year more to such supplies of spawn as can be obtained by the steamer or from the trawlers, but if these supplies are as poor as they were last year, we shall require in early summer, at the latest,

* Since the above was written the hatching boxes have arrived, and the necessary changes in the accommodation have been carried out.

to decide upon the position and nature of the spawning pond, in order that it may be completed in time for the following season.

Mr. Johnstone's work at Liverpool has been partly the investigation in the Laboratory of any specimens that were sent to us, partly assisting me in the work, and partly (with Mr. Tom Mercer) looking after the Fisheries Museum, and the Circulating Fisheries Exhibition now at Preston. A good deal of Mr. Johnstone's time in the Laboratory has been taken up with the examination of Mussels and other shell-fish, at all times of the year, and from various parts of the district. The evidence as to the spawning habits of the Mussel obtained from the microscopic characters of the reproductive organs is rather puzzling, but it now seems most probable that the Mussel commences to produce mature reproductive elements in the middle of winter,* and continues to emit eggs and sperms in small quantities for the first six months of the year (probably in increasing amount after April), during which time large eggs are always to be found in the ovary; and then, in the middle of summer, produces rapidly a much greater number of ova, so as to clear out the contents of the ovary, which suddenly (about end of July) undergoes a great change, easily recognisable under the microscope as the "spent" condition. It then, after a brief interval, proceeds to develop fresh ovarian tubules, and load up rapidly with young ova, which develop during the autumn and early winter in time to be mature at the end of the year. The full details of these changes in condition will be found in Mr. John-

* We have obtained Mussels with completely formed active spermatozoa in the middle of December. Mr. Ascroft has found the free-swimming larva at Lytham in April and May, and the first "strikes" of young Mussels are frequently found here upon Algae in June.

stone's section of the Report at p. 104, and the various stages are illustrated by two plates. I have also started Mr. Johnstone on an investigation of the structure of our edible Cockle, and hope in next year's Report to publish his full detailed account of that animal.

Our travelling "Fisheries Exhibition" is working its way through the more important towns of the county. At the beginning of March, 1898, after a very successful period at Liverpool, when it was repeatedly visited by many interested in the subject, the exhibition was transferred to the Royal Museum, Salford, where it remained till the end of October. In the meantime, a circular was issued from the County Offices, Preston, stating that this Fisheries Exhibition might be obtained on loan, on certain terms to meet the expenses of packing, unpacking, re-arranging, and carriage. Applications were received from the Museums of Preston, Warrington, Bolton, and St. Helens; and early in November the exhibition was transferred to the Harris Free Museum at Preston, where it will remain for some months. The transference of the cases and collections (which have to be very carefully packed and unpacked) from one institution to another occupies Mr. Johnstone, with the assistance of T. Mercer and a joiner, for about a fortnight, and it occasionally happens that there are specimens which become accidentally broken or damaged, or for some other reason require to be replaced from the Laboratory, and re-labelling is sometimes necessary. All this, and the correspondence connected therewith, has taken up a not inconsiderable part of our Liverpool Assistants' time during the past year; but I think we are all agreed that it is well worth doing. The collection, it will be remembered, was originally formed for the Fisheries Exhibition at the Imperial Institute in 1897, and as it mainly illustrates

our local fisheries and local investigations it is important that it should be shown *locally*, and to the people who are interested in these fisheries and who contribute to the expense of regulating them. The educational value of the exhibition must also be considerable, and may perhaps be gauged by the keen interest shown by visitors.

I can speak to that from my own experience when the collections were at Liverpool; and I may also quote a few sentences from letters sent to me by Mr. B. H. Mullen, M.A., the Curator of the Museum at Salford when the Exhibition was in that town, as follows:—

“The Fisheries Exhibition is a very great attraction here, and must be doing a lot of good. During the past three days we had almost 1,000 more visitors than during the same period in 1897. I place the greater part of this to your most interesting exhibition.” . . .

“You will notice that in those four months (June, July, August, September) last year over 95,000 persons visited our museum.” . . .

“I estimate the number of persons who visited the Museum while your exhibit was here to be 119,852—say, 120,000.”

Mr. Mullen prepared, partly from the catalogue given as an appendix in our last Report, a “Popular Guide,” which was largely sold to visitors to the Salford Museum at the price of one halfpenny. All this can scarcely fail to do much good in interesting the public in the importance of Fishery questions, and in disseminating correct and useful information as to the work of the Lancashire Sea-Fisheries Committee.

It is proposed that the Exhibition should be sent in April, 1899, to Warrington, and after that to Bolton, and then St. Helens, and any others of our neighbouring towns that can provide suitable accommodation, in the order of their

formal application.* The permanent home of the Exhibition, when not on loan, is in the Fisheries Museum at University College, Liverpool.

It may be mentioned, in this connection, that last May Professor Boyce and I exhibited at the Royal Society the practical results of our investigations on Oysters and Disease which are discussed further on in this Report.

The educational aspect of such matters naturally leads me to a question of Technical Instruction, which has arisen almost simultaneously on the Scientific Sub-Committee and at University College, Liverpool, viz.:—The formation of a “School of Fisheries Science,” or a curriculum of instruction in the sciences which underlie Fisheries knowledge and investigations. In November the Scientific Sub-Committee drew up the following report:—“Having regard to the increasing development of knowledge on Fishery questions, the Sub-Committee has considered a scheme for the establishment of a School of Fishery Science, prepared by Professor Herdman, and is now in communication with the Technical Instruction Committee of the County Council, with the view to this, or some suitable scheme for enabling students to obtain advanced instruction in Fishery Science, being adopted. It has also been considered desirable, if arrangements can be made, to allow the Sea-Fishery Bailiffs to avail themselves of opportunities for instruction in more advanced knowledge than they possess of sea-fish, their habits and food, in order that they may be able to instruct the fishermen in matters of which, at present, there is probably considerable ignorance, and upon which accurate knowledge would be advantageous.” This report was approved by the General Committee at the meeting in November.

* Applications should be sent to Prof. Herdman, University College, Liverpool.

The matter has also been fully considered by a committee at University College, which has drawn up a detailed curriculum of instruction, and the scheme now only awaits a conference between the University and the County authorities before becoming a working department in a most important branch of technical knowledge. With our extensive scientific Laboratories and the Fisheries department and Museum at University College, with our sea-fish hatchery and experimental tanks at Piel, and with the steamer and system of bailiffs under Mr. Dawson, we possess already organised and co-ordinated in Lancashire such a mechanism for instruction in Fishery knowledge from the scientific, from the industrial, and from the administrative sides, as probably does not yet exist elsewhere in the country.

If the County Technical Instruction Committee will help in meeting the necessary expenses of selected students passing through a two or three years' curriculum, and the Laboratory expenses of showing to the bailiffs and a limited number of fishermen the methods of investigation and the microscopic, chemical, and other facts which they hear about in lectures and reports, it can scarcely be doubted that much more will be done thereby in the dissemination of real and accurate knowledge than can possibly be effected by imperfect and sporadic courses of lectures to the fishermen.

Turning now to such special work as I have been able to do myself for this Report:—

(1.) I have considered it useful in the present state of affairs to discuss somewhat fully Mr. Fryer's criticism of Sea-Fish Hatching in America, which appeared in the last Report of the Inspectors for England and Wales (1898). I have had some correspondence on the matter with the United States Fish Commission, and I may

quote here the following sentences from a letter recently received from the Commissioner :—"For about ten years the Cod work has been attended with marked success, and in Massachusetts has resulted, not only in establishing the in-shore Cod fishery on grounds long exhausted, but, through favourable distribution of the fry, in extending the fishery to other waters not originally frequented by the Cod." . . . "Some investigations made a few years ago by the Commission indicated that the value of the Cod now annually taken on new grounds is at least several times greater than the entire yearly expenditures of the Commission for fish-cultural work, and is increasing each season."

(2.) The investigation into the condition of Oysters from various localities and under various circumstances, and their relation to infective diseases in man, which I have been carrying on during the last three years in conjunction with Professor Boyce and Dr. Kohn is now concluded, and our full memoir on the subject with illustrations of the detailed evidence will soon be published. I have therefore considered it right to lay before you in a special section of this report the final conclusions at which we have arrived on "The Oyster Question;" and I have appended to it a reprint (from our paper at the Bristol meeting of the British Association in September) of Dr. Kohn's account of the presence of iron and copper in certain Oysters. I think it is clear that what the public wants at present is an assurance that the Oysters they buy and eat come from grounds that are above suspicion. There is a great opportunity for an independent authority—either "Health" or "Fisheries," "Central" or "Local"—to take up the matter, and after due investigation to license or certify certain grounds or certain Oysters upon the lines I have indicated in the conclusions on p. 134.

W. A. HERDMAN.

JANUARY, 1899.

FISH HATCHING WORK AT PIEL.

(ANDREW SCOTT.)

At the beginning of December, 1897, I entered upon my duties at Piel, and at once proceeded to place everything in working order for the approaching spawning season. Various little defects in the machinery and tanks were discovered and put right. By far the most serious defect was found in the large overhead store cisterns in the tank room, where considerable leakage was taking place, making the room uncomfortable to work in. However, with some difficulty and expenditure of time, they were made fairly water-tight, and at the end of twelve months are now practically free from leaks.

The wooden hatching tanks used in the previous season were cleaned out, fresh sand put in the filtering compartments, and a constant circulation of sea-water established. All the apparatus was in satisfactory working order by the end of January.

On January 27th the steamer visited the spawning grounds in the central part of the Irish Sea, between the Isle of Man and Lancashire, where a few hauls with the fish trawl and surface nets were taken. No mature fish were obtained, but in the tow-net collections made at the "Top end of the Hole" and "On the Shoals" a few fish eggs were observed. The grounds were again visited during February, and although no spawning fish were found, a marked increase in the number of floating eggs was noticed. A quantity of living tow-net material brought into the Laboratory was found to contain three forms of fish eggs, in various stages of development—in some the larvæ were quite lively. These eggs were carefully picked out and placed in glass aquaria, with a constant circulation of sea-water. In the course of the same even-

ing a few of the larvæ hatched out, and two forms were identified, from the arrangement of the colouring matter, as being the larvæ of Cod and Flounder. The third, a colourless larva, was not identified, and only lived a few days. The Cod and Flounder larvæ lived for twelve days. By this time the yolk sac had been completely absorbed, but the larvæ made no attempt to feed, although kept supplied with plankton taken in the tow-net.

On March 9th the steamer again visited the spawning grounds, and this time secured a number of mature Cod, Haddock, and Plaice, from which a quantity of eggs were obtained and fertilized. These, however, were probably not quite mature, and at the end of the following day they had all died and sunk to the bottom of the tanks, no development having taken place. The tow-nettings contained an increased number of developing eggs of Cod, Flounder, Plaice, &c.

Amongst some living fish brought in by the steamer from this expedition was a mature female Flounder. These fish were placed in the tanks, and on the following day the Flounder was observed to be shedding its eggs. The fish was therefore taken out, and the eggs pressed out into a jar, and successfully fertilized with the milt of a male Flounder that had been captured, amongst other fishes, in the Barrow Channel by Mr. Wright, a few days previously. Development proceeded rapidly, and eight days later all the larvæ hatched out, there having been practically no mortality amongst the eggs. The larvæ lived without loss for fourteen days. The contents of the yolk sac had been absorbed several days previously. At this stage a marked mortality set in, and during the next few days the larvæ died off rapidly. Notwithstanding the various experiments tried to persuade them to feed, at the end of eighteen days all had died.

On March 16th the steamer arrived with a further supply of eggs from Plaice and Flounder. None of the Flounder eggs, and very few of the Plaice eggs, had been fertilized. On the 18th March a supply of Cod eggs was brought in by the steamer. Many of these were fertilized, and the development proceeded rapidly.

The spawning grounds were again visited on March 22nd, and a number of sailing trawlers were boarded when hauling in their nets. Many mature fish had been captured, and a supply of Cod, Haddock, Plaice, Flounder, and Dab eggs were obtained. The eggs of the Haddock, Plaice, and Dab did not fertilize, nor did many of the Cod and Flounder.

The surviving eggs of the Plaice fertilized on the 16th, of the Cod on the 18th, and of the Flounder and Cod on the 22nd, and 23rd March developed satisfactorily, hatching out at the end of eighteen, sixteen, eleven, and thirteen days respectively. Throughout these periods a considerable daily mortality was observed, which was, no doubt, due largely to the condition of the eggs when fertilized. In several cases the larvæ were clearly visible through the membrane of the eggs when death occurred.

Through the kind permission of the Fishery Board for Scotland, the steamer was allowed to visit the Clyde and trawl there for spawning fish. Three visits were made, but on only one of these, the first, were mature fish obtained, and the eggs successfully fertilized. The eggs were from Plaice, and the quantity on arrival at Piel measured 150 cubic centimeters. This was by far the greatest individual quantity of eggs received during the season. On the first visit the eggs of the Witch, Dab, Grey Gurnard, and Haddock were also obtained; but the Gurnard and Haddock eggs did not fertilize. The Dab

and Witch eggs were fertilized, and underwent partial development, but died after three days.

Development in the Plaice eggs proceeded through its usual course with scarcely any mortality, and at the end of twelve days, the hatching of the larvæ commenced, and was completed on the following day. Shortly after hatching was completed the larvæ were carefully transferred to glass aquaria, through which a constant circulation of water was maintained, and when they were a week old various experiments were tried to persuade the larvæ to feed. To one jar material collected in the filter was added; to a second, Diatoms; to a third, Copepoda; to a fourth, plankton from the tow-nets, and to a fifth, "Mussel broth" obtained by squeezing up the living shell-fish and passing the semi-fluid mass through a fine sieve. All these experiments were of no avail, and the larvæ began to die off when they reached the age of fourteen days. During the following fourteen days there was a considerable daily mortality, and at the end of twenty-nine days all the larvæ were dead, they, apparently, having made no attempt to feed, as no trace of food could be seen in the stomach when examined under the microscope.

Other expeditions were made to our own spawning grounds in search of mature fish, but no more fish eggs could be obtained.

The method of collecting fertilized eggs by the steamer is one of some difficulty and uncertainty, owing to the stormy weather sometimes experienced during the spring of the year. It may happen that just at the very time spawning fish are on the ground it is unsafe for the steamer to venture out. The collecting of eggs from fish caught in the net of an ordinary trawler is also unsatisfactory, owing to the circumstance that when the eggs are ready for shedding the least pressure on the sides of the

fish forces the eggs out. Fish caught in a trawl-net are generally mixed up with a large quantity of debris, especially after a four or five hours' drag, and the weight of this "rubbish" pressing against the ripe fish forces the eggs out before the net is emptied on deck. The majority of the eggs that are brought in to our hatchery from these expeditions, therefore, are not perfectly mature, consequently the eggs may not be fertilized at all, or if fertilized, die off before hatching out. It is from this cause that the high mortality arises.

An instance of this was demonstrated during the past season. A large female Plaice, fully distended with eggs, was brought in by the steamer from one of the expeditions, and was kept alive in one of the tanks. In the course of a few days however, it turned sickly, and to all appearances was in a dying condition. The eggs were therefore pressed out into a bucket containing a small quantity of sea-water, and mixed with the milt of a male Plaice that had been brought in along with the female. None of the eggs floated, although examination showed a number of them to have been fertilized, and to be undergoing development. The living ones were carefully picked out and placed in a jar by themselves. Notwithstanding a considerable daily mortality, development proceeded rapidly, and in a few days the little fishes were showing very clearly through the egg membranes, but only two hatched out. A number of the embryos reached the hatching-out point and then died. The two that did hatch out were feeble in their movements, and lay on their backs at the bottom of the jar. They were very different from the larvæ of the Clyde Plaice, and only lived a few hours.

It is clearly evident then, that fish eggs for hatcheries must be under the most natural condition obtainable. The only way to secure this is to collect the fish towards

the end of the previous year, or very early in the spawning season, and keep them alive in a suitable pond, allowing them to shed the eggs by their own efforts.

That the water is satisfactory for the purpose is proved by the result of the past year's hatching work. After passing through the filter it was perfectly pure and transparent, the specific gravity varying from 1.0025 to 1.0026, and the temperature from 4° C. to 4.8° C.

The mortality of the larvæ kept after hatching is very serious. Further experiments will be tried, as it may be that we have merely not yet hit upon the proper food. It may, however, be found best to set the young fish free before they reach the critical stage in their development.

OBSERVATIONS ON THE OCCURRENCE AND HABITS OF LEPTOCEPHALUS.

(ANDREW SCOTT.)

In recent years much light has been thrown upon this peculiar group of fishes (the Leptocephalidæ), which were at one time considered to be fully developed animals and classed by naturalists as such, under the generic name of *Leptocephalus*. Thanks to the observations made at Roscoff, in France, in 1886, the form then known only as *Leptocephalus morrisii*, was actually observed to change into the Conger eel (*Conger vulgaris*), and later, in 1891-95, two Italian investigators, Grassi and Calandruccio, carried on careful experiments on the *Leptocephalus brevirostris* taken in the Straits of Messina. They found that this so-called species went through a transformation, changing into the common Eel, *Anguilla vulgaris*.* So that there can no longer be any doubt now that the *Leptocephali* of the older naturalists are only the larval stages of Eels.

* Proceedings Royal Society, London, vol. LX., No. 363. Dec., 1896.

That there is still a considerable amount of definite information wanted regarding the movements and true habitat of these larvæ in our own seas, may be gathered from the fact that the records of their capture along the British coasts are few and far between.

In our surface tow-net gatherings, taken along the Lancashire coast during the past year or two, we have occasionally found a little flat, transparent fish, which has been entered on our lists as "*Leptocephalus* sp." In January, 1896, three were taken in the estuary of the Wyre, by tow-net worked from the steamer. In April of the same year, one was taken by tow-net worked off Lytham Pier. These were forwarded to us by Mr. Ascroft. In January, 1897, one was taken in the Mersey, off New Brighton, and in the year finished (1898), a number of individuals have passed through my hands, as follows:—

On April 26th, Mr. J. Wright, Chief Fishery Officer at Piel brought into the Laboratory a tow-net collection he had made in the vicinity of the north end of Roa Island, and amongst the material was a living *Leptocephalus*. This specimen was kept alive for a few days, but eventually died. Shortly afterwards, May 18th, while I was collecting young flat-fishes in the shore pools and gutters at low water in the same neighbourhood, three *Leptocephali* were captured. From that date onwards, to the end of June, when the weather and tide permitted, careful examination of the shores was made, with the result that eighteen specimens of this hitherto rare fish were obtained; others were seen but not captured.

The method adopted for the capture of these and other young fish, and which proved very successful, was the following one:—Advantage was taken of the fact that, during the ebb of the tide here, there is a rapid fall of

water, which has scooped out regular well-defined gullies in the more level stretches of the shore, and although the adjoining parts of the shore may be almost dry, there is still a considerable current sweeping down these gullies. By closing up the smaller gullies, and digging gutters between them and the larger ones, we were able to divert almost the whole of the retiring water on certain parts of the shore into one or two main gullies, which we afterwards partially closed up with stones, leaving only sufficient space in the centre to hold a tow-net. On going to these places during particular states of the ebb, which later on we were able to locate with considerable accuracy, and fixing our nets so that the water passed through them, we were able to secure practically all the material swept off a considerable area of the shore by the force of the receding tide. On favourable days, when there was no wind and the water free from suspended mud, we could actually see the various kinds of young fishes, Crustacea, &c., being carried into the net with the current. The nets were lifted up from time to time, and their contents emptied into collecting bottles. After the water had ceased running, we removed the nets and returned to the Laboratory with our captures, where they were sorted out, the fish being placed in tanks and glass aquaria. The Crustacea captured were chiefly used for feeding fish already in the tanks.

It was amongst the fish taken in this way that we obtained the majority of our *Leptocephali*. Occasionally others were captured by forcing the tow-net over the surface mud at the roots of *Zostera*, which is fairly common in some parts of our district. With everything in our favour, we could almost depend with certainty on having at least one *Leptocephalus* each time we tried for them. Sometimes we would get two, and once we cap-

tured four. At the end of June, when we ceased finding them, we had as many as fourteen *Leptocephali* living in the glass aquaria. They were then measured one by one and placed in two aquaria, which had a layer of sand on the bottom. The sizes ranged from $2\frac{6}{10}$ to $2\frac{9}{10}$ inches in extreme length, $\frac{3}{16}$ of an inch in vertical depth, from fin to fin, and about $\frac{1}{12}$ of an inch thick. They were flat, colourless, and perfectly transparent, the viscera, and the heart and its movements, being easily seen through the skin.

On being placed in the aquaria, the *Leptocephali* swam swiftly round the sides, with an undulating movement, like that of the sand-eel. They soon settled down to their new surroundings, and quickly buried themselves in the sand. The movements gone through in burrowing are exactly similar to those made by the sand-eel. The head is first directed into the sand, then by a rapid backward and forward movement of the posterior part of the body, the anterior part is forced into the sand, and finally, by a gliding motion, the posterior part disappears. During the day-time the *Leptocephali* remained hidden away in the sand. On the slightest disturbance of the water, such as would be caused by the throwing in of food, their heads would be thrust out and a rapid survey taken to ascertain the nature and position of this disturbing element. If it were food that happened to fall close to them, they would seize it without coming entirely out of the sand, and would then glide backwards into the burrow. If the food did not fall within reach, they would not venture to pursue it in daylight. On going into the tank-room at night, when all was in darkness, and suddenly flashing a light on the aquaria, it would usually be seen that the *Leptocephali* were swimming about actively, but soon retired into the sand if the light were continued.

The *Leptocephali* were kept under observation for a

week or two, when all, with the exception of two, were unfortunately lost through the overflowing of the aquaria in the night, no doubt having jumped out when the jars were full. The survivors remain alive, and at the end of November measured $3\frac{7}{16}$ inches in length, one having grown three-fourths of an inch in four months and the other slightly less. The transformation of these larvæ from the *Leptocephalus* stage was not actually observed, but on June 30th they were flat, transparent, colourless *Leptocephali*; and on August 3rd had passed into young eels, having a smoky-tinted back, silvery-grey sides, and being no longer transparent.

During the earlier parts of August numbers of young eels were found under the stones on various parts of the shore, which exactly corresponded with the appearance of the transformed *Leptocephali*.

From these observations it would thus appear that the *Leptocephali* are inhabitants of the mud, and their occasional presence in surface tow-net collections is due to their having been swept out of their burrows by the strong currents, and that they are never taken in the dredge is owing to their activity. Attempts to capture them with a tow-net when they are swimming against the current usually ends in failure.

In passing, it may be noted that all the *Leptocephali* I have obtained from tow-nettings on the Lancashire coast are identical with the hemi-larval stage described by Grassi, and many of the observations agree with those made by him, and published in his paper in the Proceedings of the Royal Society already referred to.

OBSERVATIONS ON THE HABITS AND FOOD OF YOUNG
FISHES.

(ANDREW SCOTT.)

Early in May the young flat fishes hatched out under natural conditions in the sea began to appear on all the sandy shores. By allowing the water draining down the gullies, when the tide was ebbing, to pass through a tow-net, considerable numbers were captured. Many of these were kept alive in our tanks and aquaria; some were preserved for future study, and others were examined at once to ascertain the nature of the stomach contents.

These little fish, chiefly Plaice and Flounders ranging from two-fifths to three-fifths of an inch in length, were quite colourless and transparent, the stomach and alimentary canal showing clearly through the skin. Although they had assumed the flattened character of their parents and the eye had begun to move over the head, they still swam about in a vertical manner. In the course of a day or two they were observed to have considerable difficulty in maintaining the upright position, and ere long, after a few more feeble attempts to swim vertically, they settled down to a semi-sedentary life in the sand. During the day-time they remained buried, except the mouth and eyes, and could only be detected with difficulty. In the darkness they came out and swam freely on the surface of the sand. After a few weeks, when the little flat fishes had become accustomed to their surroundings, they ceased burying themselves, and simply lay on the surface. Sometimes they clung to the sides of the jars with great tenacity.

The food of these young fishes was found to consist almost entirely of Copepoda. Collections made later on,

when the fish had grown to an inch and upwards in length, showed them to be feeding on *Mysis* alone.

From their peculiar structure, one would naturally expect that the flat fishes would be rather sluggish in their movements, and not at all particular as to the nature of their food. Far from this being the case, however, they pursue their food with much vigour and select a special diet, as is clearly shown when one examines the contents of their stomachs. The stomachs of the smaller ones, from one inch up to four inches in length, captured on the shores of our neighbourhood, are usually almost entirely filled with *Mysis*, a group of Crustacea that depend chiefly on the power to escape capture by making sudden leaps when approached by any moving object. The flat fish appear to be aware of this peculiarity, as they carefully stalk the *Mysis*, and when they get close up make a sudden spring, seldom failing to capture their prey. That the young flat fish prefer living to dead food can easily be seen by throwing a mixture of dead and living *Mysis* amongst them. The fish are always on the look out for food, and at once proceed to investigate any object that makes its appearance in their vicinity. If the *Mysis* swims or leaps away, then it is pursued and captured, but if it makes no attempt to escape, the fish will abandon it for a more lively prey. Of course, when the fish are hard pressed for food they may not be so particular in waiting until the object shows considerable signs of life before they capture it.

The older flat fishes, from four inches and upwards, captured on the Roosebeck Scars, usually feed on young shellfish, such as Mussels, &c., worms (*Arenicola*), and Crabs (*Carcinus*).

Shortly after the advent of the flat fishes, the young of the various round fishes, such as the codling, bluffin, sand-

eel, herring, goby, lumpsucker, stickleback, and lesser grey mullet, began to make their appearance in regular order; each having their own manner of capturing their prey, and all, with the exception of the young mullet, feeding on *Mysis*. Even the ungainly-looking and awkwardly-swimming young lumpsuckers are able to capture *Mysis*. They swim after their prey at, for them, a rapid rate, making sudden dashes as they pass, and usually trying to seize the *Mysis* by the middle. This is probably done to prevent too much attention being bestowed upon them by their less fortunate companions, which they would otherwise be sure to receive if the prey were captured by the head or tail. It occasionally happens that the young lumpsuckers do capture the *Mysis* by one end, and before they can swallow it another lumpsucker, usually a smaller one, has seized the free extremity. It is rather an interesting sight to see the stronger one trying to shake off the weaker, but so tenaciously do they cling to their victim, that the smaller fish is frequently in danger of disappearing after the *Mysis*. Only at the last moment does it reluctantly relinquish its hold.

The last of the young fishes to appear on the shores in the vicinity of Piel, so far as has yet been observed, are the lesser grey mullet. Numbers of these fish were captured in a well-defined gully on the east side of the breakwater joining Foulney Island to the land. They were first noticed about the middle of September, and were then fully an inch in length. The stomachs, on examination, were found to be filled with vegetable food, chiefly Diatoms, *Navicula* being the prevailing species. Later on, when they had reached the length of one and a half inches, the food was found to consist of a mixture of Diatoms and Copepoda (*Tachidius*).

There appears to be little or no difference in the food

of the young fishes frequenting the shore, and no matter whether they were captured at mid-day or mid-night, the food was always the same. On several occasions we trawled the gullies at mid-day and mid-night with a small otter shrimp net. This was found to be very successful in capturing young fish, &c.

A number of experiments were made to ascertain how far the colours of certain Crustacea protected them from falling a prey to the fishes. It was found that when semi-transparent and dark-coloured *Mysis* were put in the jars, the colourless ones were eaten before the dark. Similarly, when a large number of variously coloured *Hippolyte* (*Virbius*) *varians*, ranging from transparent to almost black were used, the transparent ones were the first to disappear. Gradually the others were captured; last of all, but very seldom, were the dark ones pursued. Are the pigmented forms less noticeable under the circumstances, or is the pigment itself distasteful?

THE PLANKTON WORK.

(ANDREW SCOTT.)

The examination of the floating plankton collected in the vicinity of the Lancashire coast has been continued throughout the greater part of the year. A satisfactory investigation of the material, and the accurate identification of the organisms contained therein, is a matter of considerable difficulty, owing to the large quantity of debris that is nearly always present.

Areas of the sea into which the contents of large rivers flow are usually contaminated with the spoil carried off the land. This finds its way into the river either by accident or intention, and the period during which the

lighter particles remain afloat depends largely upon the strength of the current that carries the material along.

Practically the whole of the Lancashire coast-line is influenced more or less by the outpouring of large rivers, such as the Dee, Mersey, and Ribble in the southern and central part, and by all the rivers flowing into Morecambe Bay in the north. Therefore, unless we can go to a considerable distance from land, our tow-net collections are almost wholly composed of vegetable debris, the land origin of which is clearly demonstrated by the presence of sporangia of ferns, seed capsules and leaves of mosses, protecting scales of leaf-buds, twigs and leaves of trees, etc.

The quantity of debris present in these local tow-nettings is, of course, subject to weather and tidal influences. After a spell of calm, during neap tides, we occasionally get a gathering nearly free from rubbish. One or two gatherings from the vicinity of the Bar Light-ship in the Mersey consisted almost entirely of the Copepod *Eurytemora*. In the summer of 1895, gatherings were taken in the Rock Channel, which contained nothing but large quantities of *Noctiluca*. This was unusually abundant throughout the southern part of our district for a few weeks, occasionally giving the water a distinct brown appearance. None of the gatherings taken in the Barrow Channel, outside of Walney Island Lighthouse, have been free from debris, and the same is true of those taken in the Ribble, off Lytham Pier, and in the neighbourhood of Nelson Buoy. Mr. Ascroft's system of placing his tow-nettings in white dishes with clean sea water, and allowing the organisms to separate out and come to the sides of the vessels, where they are secured and preserved, is a very useful one, but, unfortunately, not always practicable by our fishery officers, as their police work takes up most of their time.

After the experience gained last year, we arranged that the gatherings should be taken in more seaward positions during 1898. This has been done, but the results are very much the same as before. The weather is frequently quite unsuitable for our sailing boats to venture far from land, and on calm days rowing out to the stations is tedious and dangerous, owing to the tides.

To gain an accurate idea of the floating plankton of the Irish Sea other means will require to be adopted. The method that suggests itself as being the most convenient from all points of view, is to make use of the lightships that are anchored off various parts of our coast. There is probably sufficient current set up by the rise and fall of the tide to keep a tow-net extended. By supplying the keepers with bottles containing preservatives, tow-nets, and necessary instructions for working the nets, preserving the material collected, and the times (night or day, or both) when the collections should be taken, a more satisfactory knowledge of the plankton would be obtained. One of the men when off duty might be taken out in our steamer and shown the methods. Then the steamer could visit the lightships when convenient, say once a month, leave a fresh supply of bottles, replace worn out tow-nets, and bring back the collections taken during the interval.

The success of this method, of course, depends entirely upon (after the necessary permission has been obtained) the zeal and care of the men themselves, and the encouragement we give them.

The collecting stations which might be tried this ensuing year are the North-West, the Morecambe Bay, the Selker, and the Bahama Lightships, and if the results prove satisfactory, which no doubt they will, the system can easily be extended.

The material examined during the past year has given us results which vary very little from those already given in former Reports. The following are a few of the more noteworthy organisms observed:—

Mysis occurred in many of the gatherings throughout the year, but only a few individuals were present in each tow-netting. They were very common during the whole year in the shore pools in our neighbourhood. On September 14th, immense number of young *Mysis* were observed in the channels near Baicliff. This is undoubtedly one of the most valuable sources of food supply for young fishes.

Cragon, *Pseudocuma*, *Gammarus*, and *Eurydice* were occasionally noticed, but only one or two individuals at a time. On a warm day, when the sea is calm, numbers of *Eurydice* may be seen disporting themselves on the surface. In their movements they are not unlike the “Whirligig” beetle of the fresh-water ponds.

Copepoda—*Eurytemora*, *Acartia*, *Paracalanus*, *Temora*, *Calanus*, *Pseudocalanus*, and *Oithona*, were present more or less throughout the year, but never, as a rule, in any quantity. In a few of the gatherings from the vicinity of the Bar Lightship, *Eurytemora* was, on one or two occasions, very common. The striking difference between local and off-shore collections was clearly demonstrated by the comparative scarcity of Copepoda in-shore. As early as January 10th one-fifth part of the tow-nettings, taken by the “John Fell,” five miles north of the Selker Lightship, consisted of *Calanus*, *Paracalanus*, and *Acartia*. At the same time, only a few individuals were taken in local gatherings.

At a very early stage in the life history of most fishes, Copepoda play an important part as a food supply. The majority of the young flat fishes—Plaice, Flounder, Dab,

&c.—when they first appear on the sandy shores, feed almost entirely on these minute crustaceans. The species usually found in the stomachs of the young fishes, between half-an-inch and an inch, are chiefly littoral, such as *Eurytemora*, *Ectinosoma*, *Tachidius*, and *Jonesiella*. Although the Copepods at particular stages form a food supply for the fishes, it is just possible that the fishes themselves, when they are newly hatched, may be eaten by the Copepods. Instances of this were demonstrated during our feeding experiments, and a species of Copepod (*Centropages*) was seen to capture one week old Flounders and eat them.

Other invertebrates, such as *Sagitta*, Medusæ, Ctenophora, and *Oikopleura* occurred very sparingly in the local gatherings.

The eggs and larvæ of fish were very plentiful in tow-nettings taken in the open sea, but very few eggs and no larvæ occurred in the local collections. The first collection in which fish eggs were observed were those taken by the steamer on January 27th, at the "Top end of the Hole." None were found in local gatherings until February 4th.

Amongst the surface material collected by tow-net when the steamer was in the Clyde on April 21st, were three large fish eggs, measuring fully three millimeters in diameter. The larvæ were well developed, and hatched out a few days later, but did not survive. There was one large and one small amber-coloured oil globule present, but no space between the embryo and the egg membrane. The species of fish to which these eggs belonged is still uncertain. The only eggs corresponding to them in size are those of the Halibut; but the eggs of this fish have apparently not yet been taken in surface nets. The newly hatched larvæ had a large yolk sac and very short tail.

Larvæ of various groups of the invertebrata, including Mollusca, Crustacea, Polyzoa, Vermes, and Cœlenterata, were occasionally observed in the local collections. The floating eggs of *Alcyonium* were very common in Barrow Channel, off Roa Island, in the beginning of April, and also in the tow-nettings taken in the Clyde.

Noctiluca was very common in the collections taken in the vicinity of the Bar Lightship, Mersey, on June 24th and onwards; but was not observed in the northern part of the district until the end of August.

Ceratium tripos, *C. furca*, and *C. fusus*, occurred in many collections throughout the year.

Diatoms (*Biddulphia*, *Coscinodiscus*, &c.) were very seldom found in the local collections, but were abundant in the gatherings made by the steamer further out, in the spring months.

EXPERIMENTS WITH WEIGHTED DRIFT BOTTLES.

(ANDREW SCOTT.)

In a former Report,* under the title, "The Drift Bottles and Surface Currents," in which the result of the distribution of drift bottles over the Irish Sea, and the conclusion drawn therefrom, is given, reference is made to an experiment of Mr. Ascroft's, where, instead of using small bottles containing only the post card, larger bottles were employed, but, in addition to the post card, were so weighted with sand that they floated almost entirely submerged, and of which nearly 30% were returned. It is also incidentally remarked that some of them sunk out of sight when set free, one being subsequently brought up in a steamer's trawl while fishing in the vicinity of the Bahama Lightship on the north-east coast of the Isle of

* Report for 1895, Sect. II., p. 12.

Man. This is now accounted for by the following explanation. During transit some of the bottles were broken, but in order that the post cards should not be wasted, other whole bottles were obtained, the card and the same sand put in, then the whole sealed up, over-looking the fact that all bottles may not be of the same weight, each requiring careful ballasting, consequently when these bottles were thrown overboard the majority of them sank.

The result of this experiment of Mr. Ascroft's showed that weighted bottles tended to go south, thus differing from the light ones, which largely went to the north. In order to throw further light on this apparent southerly drift of weighted bottles, it was decided to give the weighted bottles a further trial, and in addition, by setting them free on the spawning grounds when the steamer was trawling for spawning fish, perhaps gain some definite information regarding the direction of the drift of the surface waters in which the embryos and larval fish usually are.

Accordingly we had a number of ordinary post cards having the same notice previously used, printed on the back, and we purchased a supply of bottles, known as "cocoa wine bottles," of about one pint capacity. These bottles were placed one by one floating in a bucket of sea-water of 1.0026 specific gravity, and then carefully ballasted with dry sand, so that when the rolled up and numbered post card was placed inside, the cork inserted, and the whole sealed up with paraffin wax, only about an inch of the neck of the bottle was above the surface of the water. They were then sent on board the fisheries steamer in batches, each batch being accompanied by forms having the numbers of the bottles, and spaces for the insertion of the position of the steamer when the bottle was set free,

the date, time, state of the tide, direction of the wind, and approximate quantity of floating eggs taken in the tow-nets. The forms were filled up by Captain Wignall, and returned to me, after the bottles had been set free.

Altogether 102 bottles were made up, but one of these was broken in transit, so that during the time the steamer was trawling for spawning fish, from February to the middle of May, 101 bottles were set free, of which we have exact particulars regarding their distribution. Of this number 41 or 40·5% have been returned to Piel from various parts of the coast-line of Cheshire, Lancashire, Cumberland, and the South of Scotland.

The following table gives the position of the steamer when the bottles were let off, the place where they were subsequently picked up, and the number of days that elapsed between their despatch and recovery (see p. 34):—

From this table it will be seen that nearly 22% of the bottles have drifted in an easterly or southerly direction after being set off, and nearly 18% have taken a northerly direction. Only one bottle, No. 60, appears to have crossed the head of the tide. Of the 40 set free in the vicinity of the Bahama ship, 12 have been returned, and of these eight have gone north to the south coast of Scotland, and four have taken a south-easterly direction, landing on the Cumberland coast. Bottles 51 and 53, set free within fifty-five minutes of each other, yielded rather peculiar results, the first going to Holyhead in seven days, and the second to Duddon in 47 days, distances of fifty-five miles and twenty miles respectively in a straight line from the point of despatch, but in exactly opposite directions.

Of the various days on which the bottles were found, only three were Sundays, and seven were Mondays. The conclusion naturally drawn from this evidence is, that the

bottles were probably found almost immediately after being stranded. The shores are so regularly patrolled by the people living in the immediate neighbourhood, that there is little chance of any unusual object being long over-looked. One or two of the finders stated that the bottles came ashore during the previous tide, and one was picked up at sea, five miles from Blackpool, by a fisherman, after it had been 23 days in the water.

In all probability the bottles would float slightly higher in the water of the open sea than they did in the bucket at Piel, as the specific gravity of the water at the various stations ranged from 1·00268 to 1·0027, so that there would be little chance of their going towards the bottom of the sea till they entered the estuaries of rivers.

The table shows that out of the 101 bottles set free, fully 30·6% have been stranded on the Cheshire, Lancashire, and Cumberland coasts, and therefore the result of this experiment, even with weighted bottles in place of light ones, confirms, in a striking manner, the conclusion arrived at by Professor Herdman* when summing up the results of the first series of experiments, *i.e.*, "That the embryos of fish spawning in the deep water on the eastern side of the Isle of Man would go to supply the nurseries in the shallow Lancashire and Cheshire Bays."

Fish eggs and larvæ were found in all the tow-nettings made during the experiment.

[Table over page.

* Rep. Lanc. Sea-Fish. Lab., 1895, pp. 20—21.

No. OF BOT.	POSITION.	DATE, TIME, AND TIDE.	DIREC- TION OF WIND.	WHERE AND WHEN FOUND.	No. OF DAYS
2	17 m. N.W. $\frac{1}{2}$ W. from Gas Buoy, Piel	Feb. 21, 3-30 p.m., 3 $\frac{3}{4}$ h. ebb	N.N.W.	W. side of Walney	8
3	Ditto	" 3-45 "	"	Ditto	8
5	12 m. W. from Selker Lightship	" 4-50 "	N.	Heysham	10
7	13 m. W. by N. from Selker Lightship	" 5-20 "	"	W. side Foulney	9
8	13 m. West of above ship	" 5-45 "	"	W. side Walney	7
10	Ditto	" 6-15 ", low-water	"	Ditto	13
12	10 m. N. by W. $\frac{1}{2}$ W. from Morecambe Bay Lightship	Mar. 10, 1-15 a.m., 45 min. ebb...	N.W.	Silecroft	6
13	11 m. N.N.W. of above ship...	" 1-30 "	"	Ditto	5
14	Ditto	" 1-45 "	"	Ditto	6
18	Ditto	" 2-45 "	"	Ditto	6
22	15 m. S.W. by W. from Selker Lightship	" 3-45 "	Calm.	Haverigg point	8
23	Ditto	" 4-0 "	"	Duddon	7
25	Ditto	" 4-30 "	"	Silecroft	6
27	Ditto	" 5-0 "	"	Whitbeck	6
31	4 m. S. from Bahama Lightship	Mar. 15, 6-30 ", 3 h. ebb	S.W.	Haverigg point	20
46	5 m. E. by N. of ditto	Mar. 16, 12-45 p.m., 1 $\frac{1}{2}$ h. fl.	W.S.W.	Seascale	8
47	Ditto	" 1 p.m.	"	Ditto	8
50	5 m. E. by S. of Bahama Lightship...	" 2 p.m.	"	Nethertown	5

51	17 m. W.S.W. of Blackcombe	...	Mar. 22, 12-20 p.m., 1 h. ebb	...	W.N.W.	Holyhead	29	7
53	Ditto	...	" 12-55 "	...	"	Duddon	" 8*	47
59	13 m. S.W. by W. 4 W. from Selker ship	...	" 2-25 "	...	"	Haverigg	Apr. 20	29
60	Ditto	...	" 2-40 "	...	"	Powillimount	" 18+	27
63	19 m. W. of Blackcombe	...	" 3-15 "	...	"	Duddon	" 12	21
68	18 m. ditto	...	" 4-30 "	...	"	Boothle	" 11+	20
69	16½ m. ditto	...	" 6-40 "	...	"	Askam	" 12	21
73	¾ m. from Bahama ship	...	Apr. 12, 11-30 a.m., 3 h. fl.	...	N.	E. side Wigton Bay	" 19	7
74	Ditto	...	" 11-50 "	...	"	Gatehouse	" 22	10
76	½ m. E. ditto	...	" 12-15 p.m.	...	"	Garliestown	" 20	8
80	2 m. E.N.E. ditto	...	" 1-30 "	...	"	Ditto	" 20	8
81	1 m. S.S.E. of Bahama ship	...	" 6-30 "	...	S.W.	Wigton	" 26	14
86	Ditto	...	" 7-45 "	...	"	Isle of Whithorn	" 23	11
87	Ditto	...	" 8 "	...	"	Mull of Galloway	" 29	17
90	Ditto	...	" 9 "	...	"	Garliestown	" 22	10
92	10 m. W. of Morecambe Light Vessel	...	May 19, 12-15 "	...	E.N.E.	Hoylake	June 2	14
95		...	" 1 "	...	"	New Brighton	" 3	15
97		...	" 1-30 "	...	"	Knot-eid	July 4+	47
98		...	" 1-45 "	...	"	Altcar	June 2	14
99		...	" 2-0 "	...	"	Blackpool	" 20+	32
100		...	" 2-30 "	...	"	At sea 5 m. from B'kpool	" 11	23
101		...	" 2-45 "	...	"	Blundellsands	" 4	16
102	to 16 m. W. by N. of same ship	...	" 3 "	...	"	Altcar	" 5*	17

* Sundays.

† Mondays.

THE SPAWNING OF THE MUSSEL (*Mytilus edulis*).

(J. JOHNSTONE.)

During the last year an investigation of the reproductive organs of the common Mussel has been made in relation to the period during which spawning takes place on the beds along the Lancashire sea coast, and to the histological changes accompanying the ripening and extrusion of the reproductive products. The methods employed were:—(1) The microscopic examination of the gonads of specimens taken by Mr. A. Scott from the Roosebeck scars and the beds in the Barrow Channel, and of specimens sent by the bailiffs from the Wallasey, New Brighton, and Morecambe beds; (2) the search for free-swimming and fixed larvæ on the beds themselves, and (3) the examination of the in-shore tow-nettings taken by Mr. Wright in Morecambe Bay, and by Mr. Eccles outside the estuary of the Mersey. The records of a continuous weekly series of tow-nettings, taken in the year 1895 by Mr. R. L. Ascroft, at Lytham Pier, have also afforded valuable evidence.

As a result of this year's observations, it has been found possible to fix approximately the date of a maximum in the spawning of the Mussel, during which a rapid and complete extrusion of the genital products, accompanied by other histological changes in the mantle and visceral mass of the animal, takes place. In the year 1898 this was found to begin about the beginning of July and last till about the beginning of August; but it is probable that the limits of this period are variable to some extent. There is, however, considerable doubt as to whether this is the only time in the year during which spawning takes place, and various observations render it at least possible that there is a secondary spawning period early in the year, and that there is a continual but slow emission of ova and

spermatozoa from the time when these have accumulated in considerable quantity in the gonads, that is to say, from the beginning of April on to the beginning of the summer spawning period. And it seems certain, considering the variability observed in the ripening of the gonads, that isolated individuals may undergo complete spawning a considerable time in advance of, or later than, the date of occurrence of the maximum. However that may be, there can be no doubt that the number of larvæ resulting from spawning in the early part of the year bears a very small proportion to those produced during the maximum spawning period in the summer months.

There is still some uncertainty regarding the rate of growth of the young Mussel, and this is due probably to variations contingent on the conditions under which the adult animal spawns, and the larva undergoes its early development. Most probably in the early stages during which the young Mussel has a free-swimming existence, the development and rate of growth are fairly constant, but with the acquisition of the byssus and the fixation of the larva, the subsequent growth is dependent, to a large extent, on the situation it finds itself in, the supply of food, the extent to which the larvæ are crowded together, and on the time of year in which spawning of the parent occurred. From the observations made by Wilson,* who succeeded in artificially fertilizing eggs of the Mussel, and tracing out the early development, it appears that the larva, about 0.15 mm. in length, provided with semicircular valves, showing the first rudiment of the anterior adductor muscle, and still using the velum as a locomotive organ, is at most 12 days old. An older stage than this, with the

* J. Wilson.—“On the Development of the Common Mussel.” Annual Report of the Fishery Board for Scotland for the year 1885, pp. 218—222, and Report for 1886, pp. 247—256, Plates XII.—XIV.

valves assuming an oval form, the foot developing, the posterior adductor muscle present, rudiments of four gill filaments appearing, and the velum still functional is, at the outside, a month old. Subsequently to this (0.28 mm. long) blue pigment is deposited round the margin of the shell, the foot becomes the organ of locomotion, and the larva prepares for fixation by the development of byssus gland and byssus.

Free-swimming larvæ, somewhat younger than the stage last referred to, that is, about 0.25 mm. in diameter, and provided with circular valves showing no trace of pigment, were taken by Mr. Scott in a tow-net gathering at Piel, on September 9th, last year. These Mussels were certainly less than one month old, and their appearance at this time is in accordance with anatomical observations made on specimens taken in the neighbourhood, which led us to fix July and early August as the months during which spawning took place. But the evidence given by other observations of this kind is very perplexing. Thus young Mussels with circular or oval valves ranging in size from 0.27 to 0.45 mm., and with the rudiments of four or more gill filaments present, were taken in June, 1892, fixed to various zoophytes, and assuming the age of these not to exceed a month, the time of spawning is thrown back to May or early June. An examination of the in-shore tow-nettings shewed that young Mussels of approximately this size (0.3 to 0.6 mm.) were taken in the estuary of the Ribble on January 27th, 1898, and others, varying in size from 0.2 to 0.7 mm., were found in Ulverston Channel on February 4th. Some of these had probably been already fixed and were loosened by the force of the tide, but others had all the characters of the free-swimming stages described above, and their presence at this time is only explicable on the assumption that

there had been considerable retardation in the rate of growth, or that they had resulted from spawning early in the year. The early maturity of the spermatozoa is interesting in this connection. In some specimens taken in December by Mr. Scott, ripe spermatozoa, which remained alive for about 12 hours, were expressed from the mantle lobes. An attempt was made to bring about artificial fertilization, but although the eggs were found to be covered with motile spermatozoa, and in some cases the formation of the first polar body took place, the segmentation of the ovum was not observed.

The assumption that some Mussels at least may spawn early in the year is necessary to explain the presence of larvæ in January and February, if it should be found impossible to account for the presence of such by considerable variation in the early development and rate of growth; and that there is a gradual emission of spawn during April, May, and June seems probable also in view of the fact that free-swimming larvæ are to be found in May and June. But from the anatomical standpoint, such secondary spawning periods are accidental, and do not effect the statement that there is a yearly cycle of changes in the reproductive organs of the Mussel, which begins with the termination of the act of spawning sometime in the summer months, includes the gradual and continuous ripening of the gonads, and ends with a comparatively rapid extrusion of the reproductive products, leaving the animal in a "spent" condition, after which a short period of rest occurs, and the cycle of changes is repeated. The duration of the maximum spawning period we have not precisely made out, and its date is probably variable and dependent on changing meteorological conditions, but that it occurs during May, June, July, and August seems perfectly certain. This cycle of changes will now be considered.

It will be remembered that in the common Mussel the sexes are separate. Hermaphrodites, if they exist, must be extremely uncommon as, in the examination of many hundreds of specimens, none have been observed. There is a slight preponderance of males over females, the ratio in 218 specimens examined being 118 : 100 ; but it is probable this is too low, as it is hard to avoid selection in choosing the specimens for examination.* Except for a slight difference in the colour of the mantle lobes there are no external sexual characters.

The gonad (Pl. I., fig. 2) is situated in the visceral mass and mantle lobes; the organ is paired and bilaterally symmetrical, and consists of a branching tubular gland, the efferent duct of which is situated on the summit of a small papilla (Pl. I., fig. 1, *pp. gen.*), about 1 mm. in height, which lies posterior to the foot and immediately beneath the gills (*br. R.*), and can be easily seen by reflecting the latter and the mantle (*Mn. R.*). This duct is richly ciliated for some distance internally, when the ciliated wall is partially replaced by germinal epithelium. Strips of columnar ciliated epithelium (Pl. II., fig. 7, *ep. cil.*) are present along the greater length of the tubules, but the terminal portions are entirely lined by germinal epithelium. Passing inwards these tubules branch

* Since the above was written the tabulated results of the examination of the specimens sent to the Laboratory by the Bailiffs have been referred to. The portion of these records dealt with relates to the examination of a large number of Mussels taken at random from most of the Mussel beds in the district, and sent to the Laboratory in lots of a dozen each, and extends over the years 1892-96. In order to eliminate as many sources of error as may be possible, all those sheets in which the sex of one or more of the specimens is regarded as doubtful, and also those dealing with Mussels taken about the time of the "spent" period, have been rejected. This leaves a total of 821 specimens of which the sex was probably accurately determined. Of these 449 were male and 372 female, giving a ratio of males to females equal to 6 : 5 (very nearly).

repeatedly and in quite an irregular manner. Anastomoses between the various branches have been figured by Wilson, but we have not seen these. All along the course of the main branches small twigs are sent out, some no longer than their own diameter, and these grow and invade whatever portions of the body they can find room in. The gonad thus occupies no particular part of the body of the animal except that the position of the external opening is constant, but it may be conveniently said to be situated posteriorly to the digestive gland, and as ripening proceeds, to invade every part of the body, where only connective or parenchymatous tissue is found (Pl. I., fig. 2, *tub. ov.*). Simultaneously with the encroachment of the genital tubules, this tissue undergoes absorption or degeneration. The keel-like mass, the "abdomen," (Pl. I., fig. 1., *abd.*) situated medially and posteriorly, is thus completely filled up by the organ, and as maturation goes on, the whole space in the mantle lobes (Pl. I., fig. 2, *Mn. L.*; *Mn. R.*), between the internal and external epidermal surfaces is filled up by the branching tubules of the gonad and except for the merest trace of connective tissue contains nothing else. Long before spawning occurs these tubules have invaded almost every part of the body (Pl. I., fig. 2), even the delicate membrane forming the external wall of the pericardial cavity being overspread by them and becoming opaque. With the act of spawning the whole appearance of the animal may be changed, owing to the emptying of these tubules of their contents, and the mantle lobes may lose their thick and opaque appearance, and become thin and transparent. This is the case in the Mussels in some of the beds in the district, but more usually the mantle lobes remain thick and opaque. After spawning it is only by microscopic examination that the condition of the animal can be determined.

As indicated above, the cycle of changes in the gonads is a yearly one, or approximately a yearly one, variations due to the nature of the season doubtless taking place. This cycle of changes may be represented by four stages. In giving the dates, we refer more particularly to what was found during the year 1898

STAGE I.—The end of *July* and the beginning of *August*. The Mussel is “spent,” that is, the reproductive products have been entirely extruded, and in the mantle lobes and visceral mass the genital tubules are, to a large extent, collapsed or degenerated. The state of the animal in respect of its reproductive function is one of rest.

STAGE II.—*September*. The gonads have begun to invade the mantle lobes and other parts of the body. Proliferation of ova and spermatozoa from the germinal epithelium is in progress, and goes on slowly and continuously from now till early in the following year, when it becomes very active, and the mass of the gonads becomes much greater.

STAGE III.—*April*. The mantle lobes have attained their maximum of thickness, and are completely filled up by the gonads. The tubules composing the latter have increased greatly in sectional area, and are completely filled up by ova or spermatozoa in female and male respectively. Proliferation from the germinal epithelium is not now so active as in the earlier part of the year, and maturation of the genital products probably goes on. Where the ova or spermatazoa are in contact with the ciliated portions of the tubules, they are probably being swept away and removed out of the body.

STAGE IV.—*July* and early *August*. Spawning in the sense of a complete removal of the genital products is now in progress. There is a rapid decrease in the mass of the gonads, both in visceral mass and mantle lobes,

and a corresponding increase in mass of the parenchymatous tissue lying between the tubules. Many of the branches of the tubular gonad disappear entirely, but many others, and particularly the ciliated, non-glandular portions, persist *in situ*. At the end of this period, when the animal again enters on Stage I., the parts of the body formerly occupied by the swollen genital tubules are now the seat either of a massive syncytial tissue, or of a delicate reticulum, the difference depending probably on the condition of nutrition obtaining on the bed from which the specimen was taken.

We may now consider the characters presented by the animal in the various stages referred to more particularly.

STAGE I. (Pl. II., figs. 3, 4, 6).—Externally there may be nothing to indicate that the specimen under examination has spawned, although in a section, or in a cleared preparation, the difference between this stage and the preceding one is striking. The sex of the animal is determinable only with some difficulty, by the presence of stray masses of ova or spermatozoa, which have failed to be extruded. Where the germinal epithelium can be recognized, it is not very different in male and female. The area in a section of the mantle now occupied by the tubules of the gonads is so greatly reduced that, on a superficial examination, it might be thought that the latter had completely disappeared. But more careful scrutiny reveals the presence of many tubules in a collapsed condition (Pl. II., figs. 3, 4, *tub. ov.*), the walls pressed against each other by the pressure of the reticular tissue. It is, however, only the larger tubules which so persist; the finer branches have been absorbed or broken down in some way.

The space occupied in the ripe Mussel by the gonads is now filled up by a large celled parenchymatous tissue

(Pl. II., fig. 3, *ret.*) of peculiar characters. This tissue which, in the ripe Mussel, was represented by a few delicate fibres, lying wedged in between the tubules, has now increased greatly in mass, and occupies almost the whole thickness of the mantle lobes. It does not, like the corresponding tissue in the Oyster, consist of cubical or polygonal cells, with clear bodies arranged to form a coarse network, the bars of which are composed of distinct cells, but is rather a syncytium, in which cell outlines cannot be readily distinguished. The surfaces of attachment of the parts to each other are large, but occasionally delicate fibrous connecting strands may be found. The cells are multinucleated, an isolated patch may be seen to possess several nuclei, but no trace of cell walls. The cell substance stains deeply with eosin. In moderately thick sections it appears to be dotted over with small, light, circular areas, but in thinner parts these are seen to be vacuoles, possibly filled with a substance which does not readily stain.

The epidermis (Pl. II., fig. 3, *ep. ext.*) of the mantle is formed of a single layer of cells, with large nuclei and rather indistinct cell walls. On the internal face of the mantle this epidermis is ciliated. Beneath it there may be a layer of longitudinal fibrous tissue, but this is not constantly present. The reticular tissue of the interior of the mantle is connected with the epidermal layer by delicate strands, but occasionally large rounded masses may be seen lying beneath the former. The epidermis contains eosinophilous cells forming projections internally and externally. Blood vessels are abundant along the external face of the mantle (Pl. II., fig. 4, *bl. sp.*). The larger of these have a fine endothelial lining the structure of which is difficult to make out. These, as well as the interspaces of the reticulum beneath the epidermis, may be crowded with blood corpuscles.

The characteristic of this stage is the enormous development of this reticulum, which has all the characters of a tissue produced by the rapid multiplication of nuclei, without a corresponding differentiation of cell bodies and walls. In some sections the space occupied by it is so great, that the appearance is almost that of a homogeneous nucleated matrix, perforated in many places.

The description given of this stage applies to the Mussels obtained from the Wallasey and Morecambe beds, the Roosebeck outer scar, and from those in the Barrow Channel. Mussels obtained from the Roosebeck inner scar have different characters in respect of the condition of the gonads at this stage, and these are probably correlated with the different conditions of nutrition obtaining on this bed, which have been commented on in a former Report.* Spawning in these Mussels leaves the mantle lobes delicate and transparent. The reticular tissue has the form of an attenuated network of large mesh, and, in consequence of this, the remains of the genital tubules are more easily seen, and a resting stage is not so conspicuous.

STAGE II. (Pl. II., fig. 7; Pl. I., fig. 2).—The period of rest which follows immediately after spawning, and which is represented by Stage I., is of short duration, and as early as the beginning of September the developing gonads may be seen in the mantle. There can be no doubt that, after spawning, many of the tubules break down and disappear, but it seems quite clear that the more important branches persist in the mantle through the period represented by Stage I. Towards the end of September ripening has commenced, and proliferation from the germinal epithelium is in progress. At any

* A. Scott. "Mussels and Mussel Beds." *Lanc. Sea-Fish. Laby. Report* for 1895, pp. 21—32.

stage this process is further advanced in the male than in the female. During September the tubules are of small diameter, no greater than that of an interspace in the reticulum. The structure of the cells composing the germinal epithelium of this stage is nearly similar in both sexes. An irregular layer of cells is supported on a basement membrane. The female germinal epithelium (Pl. II., fig. 7, *ep. ger.*) can be distinguished by the large nuclei of the cells. At this stage it consists of few cells, and the first few ova separated off fill the lumen of the tubule. Proliferation is a more rapid process in the male, and in a short time the tubules are filled with cells, resulting from the divisions in the germinal epithelium. Most of these cells become spermatoblasts, and divide subsequently to form the spermatozoa, but many of those separated off at this stage become modified to form the system of supporting filaments so conspicuous at later stages (Pl. II., fig. 5, *sup. fil.*) The cell migrates towards the centre of the tubule, becomes slightly elongated in a radial direction, and its outer end becomes frayed out into one or more delicate filaments, which seem to retain some connection with the wall of the tubule. The nucleus and cell body then break down and disappear, and a group of filaments is left arranged radially in the lumen of the tubule, on which the spermatozoa formed at this time, and subsequently are arranged in rows. In the smaller and terminal portions of the tubules the whole epithelium takes part in the formation of spermatozoa or ova, according to the sex, but in the larger branches, and this is the more common appearance in the sections, the tubule possesses a longitudinal strip of columnar epithelium, cells with clear cell bodies, and with long cilia projecting into the lumen. This strip of ciliated epithelium extends round the tubule for about one-fourth or less of the cir-

cumference. It is more common in the male gonad, but is present also in the female.

The parenchymatous tissue between the tubules has much the same characters as in Stage I., but it is now arranged in a more even system of bars and is not so massive. Certain appearances, such as the difficulty of distinguishing the limits of the growing tubules in relation to the surrounding reticulum, seem to indicate that the gonads grow at the expense of this tissue, or at least absorb it during the process of growth. It was, however, impossible to demonstrate this with certainty in the preparations studied.

Ripening of the gonads proceeds slowly from now on to the end of January, and consists of a gradual increase in the width of the already-existing tubules and of the formation of side twigs. The contents of the tubules slowly increases, and it must be understood that from November onwards there is an increasing number of free and apparently mature ova and spermatozoa in the gonads. The fact that moving spermatozoa may be obtained from the mantle at the end of the year has been already referred to. Whether the genital products present in the gonads at the end of the year are fully mature and are capable of development is uncertain, but if so, the presence of free-swimming larvæ in the sea about this time may be easily explained, since ova and spermatozoa may be swept out of the lower partially ciliated tubules, and fertilization may result. But a certain time may also be required for the complete maturation of the genital products after their proliferation from the germinal epithelium.

STAGE III. (Pl. II., figs. 1, 2).—About this time the mantle lobes have attained the maximum of thickness, and the gonads have invaded every part of the body unoccupied by the other organs, even the outer wall of the

pericardial sac being overspread by them. The whole space between the internal and external faces of the mantle is now filled up by the gonads, and the tubules of the latter are filled, in female and male, with a dense mass of ova and spermatozoa respectively. The spermatozoa are arranged in rows on the radial-supporting filaments already mentioned, and the mutual pressure of the ova against each other in slightly later stages than this gives them a polyhedral form. The germinal epithelium is still undergoing proliferation, but this is not so active now. Where, in the male, the walls of the tubules are closely compressed together, the basement membrane can be seen as a thin, homogeneous line, on either side of which is an irregular row of large, rounded cells, with clear cell bodies and conspicuous nuclei, and internal to this the tubule is filled with a mass of radially-arranged rows of spermatozoa. The conspicuous reticular tissue present in earlier stages is reduced to the merest trace, and is present mostly at the angles formed at the junction of several tubules. It stains less intensely with eosin, but the peculiar vacuolated appearance already referred to still exists. Here and there it is present as rounded masses possessing single nuclei, but it is mostly fibrous.

As in the male, the germinal epithelium still exists in the female, and ova are still being separated off. Most of the eggs lie freely in the cavity of the tubule in contact with each other, but some are still attached to the wall by a short stalk. In some parts the wall of the tubule seems to consist of the basement membrane only.

STAGE IV. (Pl. II., fig. 5).—From April onwards there is apparently little change in the appearance of the gonads. The maximum development, as indicated by the increase in mass of the tubules, the numbers of ova and spermatozoa liberated from the germinal epithelium, and the

reduction of the other tissues in the mantle, was obtained in the specimens taken during April. Some taken later were, indeed, less advanced, but generally this seems to be the time at which proliferation from the walls of the tubules mainly ceases. In July, Mussels were taken in which spawning was in progress. In these the females had almost completely spawned, and in the males the gonads had undergone a great reduction in mass. A few stray eggs lay scattered over the section situated in tubules of greatly reduced diameter, one egg being present, as a rule, in the cross section of the tubule, and generally nearly filling it. Many tubules were completely empty. The germinal epithelium persisted in some of these tubules as one or more layers of small, rounded cells, but more often its structure was difficult to make out.

The reticulum so apparent in Stage I. is already formed, but in structure is more spongy than in the stage following the complete extrusion of the ova, and the spaces between the bars are about equal to those occupied by the tissue itself. These interspaces have, in many cases, a circular outline, and probably represent the former situation of ovarian tubules. The general histological characters of the tissue are similar to those described in Stage I., except that the vacuolated appearance is not so apparent.

The most striking changes have occurred in the male. In some of the specimens taken at this time extrusion of the spermatozoa has been almost completely effected, but in others the animal had been taken in the act (Pl. II., fig. 5). Here the sperm tubules have been greatly contracted in cross area, and the mass of spermatozoa (Pl. II., fig. 5) within the tubule has become correspondingly denser. The reticulum has increased enormously, and as it seems difficult to derive this tissue from the exceedingly fine fibrous network present in the last stage, it is possible

that it has spread into the spaces surrounding the tubules of the gonad from other parts of the body. Round each tubule this reticulum forms a dense mass, with few or no interspaces, and its syncytial character is here strongly suggested. The nuclei are not so evident as at a later stage. Within the tubule itself the linear arrangement of the spermatozoa is very striking, but instead of being directed towards the centre these rows point towards that part of the wall lined with the strip of ciliated epithelium already described (Pl. II., fig. 5, *ep. cil.*). Often a blood space (*bl. sp.*) is situated beneath this epithelium; over the cilia and within the tubule is a space free from spermatozoa. The wall of the tubule has become indistinct from the mass of spermatozoa which seem to abut directly on the tissue of the reticulum (*ret.*) surrounding the tubule. The whole arrangement strikingly suggests the exercise of pressure on the tubule by the rapidly developing reticulum and the removal of the genital products brought into close contact with the ciliated strips of the tubules. The lower conducting portions of the gonads are entirely lined with ciliated epithelium, and once here the genital products must be speedily removed.

Briefly summarised then, the history of the yearly change in the reproductive organs of the Mussel is as follows:— (1) There is a short period of rest following spawning, and occupying some part of August and September, during which the space in the body of the animal formerly occupied by the gonads is largely filled up by a large-celled reticulum. This is followed by (2) the reformation of the germinal epithelium and a slow proliferation of ova and spermatozoa, lasting for the rest of the year. During this period the gonads increase greatly in mass, and invade the mantle and other parts of the body, displacing the reticulum formed during spawning. Succeeding this is a period

(3) of active formation of the genital products, ending late in the spring, after which ova and spermatozoa are formed less rapidly. A slow emission of these now goes on until in the summer, about June or July, the maximum spawning period of the Mussel occurs.

It is unlikely that any great proportion of the larvæ found during the course of the year are spawned otherwise than at the maximum spawning period in the summer months. We have seen that it is probable that a certain proportion are spawned during the first half of the year, but that these probably result from the spawning of isolated individuals or from the slow emission of ova and spermatozoa prior to the act of spawning proper, and the fact that this occurs does not materially affect the general statement that the Mussel spawns in the summer. For the year 1898 we have fixed this spawning period as having occurred during July, but it is probable that it is variable, and as the Committee's bye-law fixes the months of May, June, July, and August as those during which it is illegal to take Mussels from the beds in the district, it is very probable that, notwithstanding some considerable variation in the occurrence of this period, it will always fall within that close time. Probably spawning is very generally over before August begins, but of this further evidence is wanted.

EXPLANATION OF THE PLATES.

PLATE I.

Fig. 1. Dissection of an adult Mussel to show the external opening of the gonad. The right valve has been removed, and the right gill and mantle lobe cut away close to the junction with the visceral mass and reflected upwards. Full size. α — β indicates the plane of the section shown in fig. 2.

- Fig. 2. Complete transverse section through the body of an adult female Mussel passing through the pericardial cavity just posterior to the heart. Note the presence of ovarian tubules in every part of the section, the stage of development being the same both in mantle lobes and in visceral mass. The specimen was taken about the end of September, and proliferation of ova from the germinal epithelium is beginning, but the diameter of the tubules is still very small. $\times 5$ diameters.

PLATE II.

- Fig. 1. Transverse section of mantle of nearly ripe female Mussel from Roosebeck outer scar, taken during March. The mantle is nearly filled with the tubules of the gonad containing many free ova. The germinal epithelium is still undergoing proliferation. $\times 40$ diameters.
- Fig. 2. Transverse section of mantle of nearly ripe male Mussel from Roosebeck outer scar. (March.) The mantle is filled with sperm tubules. $\times 40$ diam.
- Fig. 3. Transverse section of mantle of female spent Mussel from New Brighton beds, taken during August. The tubules of the gonads have in many cases broken down. Two are shown in the section, one containing an egg which has not been extruded during spawning. Note the great development of the reticulum. $\times 200$ diam.
- Fig. 4. Transverse section of mantle of spent female Mussel from the beds in the Barrow Channel (August). A blood space lying immediately beneath the epidermis is shown, beneath which are two collapsed ovarian tubules. Note that

each is lined partly by ciliated and partly by germinal epithelium. $\times 200$ diam.

Fig. 5. Transverse section of mantle of spawning male Mussel (New Brighton beds, July). A sperm tubule is shown, partly lined with ciliated epithelium. Note the great development of the reticular tissue. $\times 230$ diam.

Fig. 6. Transverse section of mantle of completely spent female Mussel (Barrow Channel, August). $\times 35$ diam.

Fig. 7. Portion of transverse section of mantle of female Mussel (Barrow Channel, September 30). A developing ovarian tubule is shown. Actual size = 0.568 mm. Note the proliferating germinal epithelium, and the ciliated strip of wall. $\times 660$ diam.

REFERENCE LETTERS.

abd., abdomen; *add. a.*, anterior adductor muscle of the shell; *add. p.*, posterior adductor muscle of the shell; *br. R.*, right gill; *br. L.*, left gill; *bl. sp.*, blood space; *cr. st.*, crystalline style; *ep. ger.*, germinal epithelium; *ep. cil.*, ciliated epithelium; *ep. ext.*, external epidermis of mantle; *int.*, intestine; *Mn. L.*, left mantle lobe; *Mn. R.*, right mantle lobe; *per.*, pericardial cavity; *per. gland.*, pericardial gland and auricle; *pp. gen.*, right genital papilla; *pa. d.*, right dorsal labial palp; *pa. v.*, right ventral labial palp; *ren.*, renal organ; *ret.*, reticulum of mantle; *ret. bys.*, retractor muscles of the byssus; *ret. bys. in.*, insertion of retractor of the byssus into the shell; *rect.*, rectum; *sup. fil.*, supporting filaments in sperm tubule; *st.*, tubular portion of the stomach; *sp.*, rows of mature spermatozoa; *tub. ov.*, ovarian tubule; *visc. nv.*, visceral nerve cord.

ON SEA-FISH HATCHING.

(W. A. HERDMAN.)

In the Twelfth Annual Report of the Sea-Fisheries Inspectors for England and Wales (1898), under the marginal heading "Sea-Fish Hatcheries" (p. 29), Mr. C. E. Fryer enters upon such a severe and detailed criticism of the results attained that it cannot be regarded as other than an attack upon the practice of artificial hatching of sea-fish eggs as developed in America. It is fair to say that it is the results of the hatcheries in America that are attacked, as, although Scotland and Norway are mentioned, these countries are treated very briefly, and no conclusions are drawn from the few statistics quoted. The greater part of the discussion deals, then, with Canada, Newfoundland, and especially the United States. I gather that Mr. Fryer has not himself visited the hatcheries he discusses, and that his information is entirely derived from the published annual reports—an unexceptional source, so far as it goes, but one which may usefully be supplemented by personal impressions and conversation with those engaged in the work.

I regard Mr. Fryer's paragraphs as a most useful statement, drawing attention to the present position of the hatching question from the critic's point of view, counter-acting any exaggerated opinions that may have been expressed, and impressions that may have been entertained, in regard to the immediate and enormous results to be obtained from artificial operations, but requiring some criticism, some modification, and some additions before it can be accepted as a wholly satisfactory statement of the matter. For although Mr. Fryer seems rather carefully to avoid drawing any formal conclusions, he

certainly, consciously or unconsciously, by his manipulation of the statistics, conveys to the reader an impression entirely adverse to sea-fish hatching. And this impression is, I believe, derived mainly from statements in regard to the difficulty and not in regard to the efficacy of the operations.

Mr. Fryer's remarks are largely directed towards removing impressions that may prevail as to the *simplicity* of artificial hatching; and here we, in common with all who have taken any part in such work, readily concur in the general conclusion that the work is sufficiently difficult and troublesome, if pains be taken to attain success. I do not think that amongst those in this country who have had to obtain in mid-winter or early spring the spawning fish or the fertilized spawn, who have had to filter the sea-water and watch day and night its purity, salinity and temperature, who have jealously guarded the embryos from danger and have tried to obtain suitable foods for the larvæ, there can ever have been any fond delusions as to the simplicity of the business. The work is hard, there are many difficulties, the operation is a delicate one, requiring constant and intelligent attention; but all that need not deter. Given suitable conditions and the right men, and the work can be successfully carried out.

While agreeing with Mr. Fryer that "simplicity" is a delusion, I must demur against an impression which his pages are liable to convey. It must be remembered that the harrowing descriptions on pp. 36 and 37 of fish perishing in the nets owing to the heavy storms, and freezing in the boats and on the cars, and of embryos killed by the million in the hatching boxes on account of the intense cold, refer to conditions on the coast of North America, and do not apply to our seas. These exceptional difficulties either do not exist or are only present in quite a minor

degree for very short periods in our warmer and more protected coastal waters.

Turning now to the question of efficacy, we meet with this difficulty—Mr. Fryer apparently does not accept the turning out of millions of healthy young fry into the sea as a proof of successful hatching operations. He seems to demand a demonstration that the number of adult fish in the neighbourhood has increased, without taking into account the fishing operations that may be going on. In asking for immediate proof that the fry live to become adult fish the opponents of fish hatching are taking up what may seem a very secure, but is, I consider, a very unreasonable position. So many factors enter into the case that it is almost impossible to devise a crucial experiment, or give immediate scientific proof of a result. The demand may possibly be satisfied in any locality next year, or the answer may be delayed for 10 years or for longer; and yet the fisheries may all the time be largely benefitted by—may owe their continued existence to—the artificially hatched fry added to the population of the sea. And this may be the case *even if not a single individual out of the millions of fry set free ever lives to become adult.*

I do not think it at all probable that such unfavourable conditions ever exist, but I wish to point out that even in such an extreme case the expenditure on land and the sacrifice of life of the fry in the sea will not have been in vain. If we try to realise the struggle for existence in the sea, the toll that is taken at every period of life from the egg to the adult, but which is exceptionally heavy in young stages, a moment's reflection will show that the addition in any natural hatching area of some millions of young fish must distribute the danger of being caught by an enemy over a much larger number of individuals and so give to each a greater chance of

escape. And if—as may be the case, we do not know—the naturally hatched fry are hardier or more active, then they will be the more likely to survive the perils, and will owe their continued existence and their appearance in due course somewhere as marketable fish to the presence for a time in the sea of their brethren from the hatchery.

I shall come now from these general considerations—to which Mr. Fryer does not seem to give enough attention—to some of the detailed statements in his report as to the results of hatching, and upon some aspects of which, such as the mortality in captivity, in my opinion he lays far too much stress. I cannot now go into every point upon which we may differ more or less, but shall take up his treatment of the United States statistics, as they are, perhaps, the most important, and the ones discussed at greatest length.

After quoting (p. 39) the statistics of the Cod operations at the Wood's Holl Hatchery, he admits that the figures show "successful results." He then attempts to upset this conclusion by arguing that in computing the number of eggs and fry derived from a parent fish we should take into account not merely the actual parents, the fish that spawned, but also all the others that were penned up in the spawning pond. This is surely a most unjustifiable procedure. What reason is there to think that these non-spawning fish would have spawned if left in the sea? In fact, if the object is to make a comparison between natural and artificial conditions, surely from what we know of life in the sea it is highly probable that some of the fish that spawned in captivity would, if left at large, have been destroyed by man, or their natural enemies, before they became parents. Consequently, I consider that the Superintendent of the Hatchery was perfectly right in considering as parent fish only those from which

spawn was obtained, and I should remove from Mr. Fryer's table, at the foot of p. 39, the three columns headed "penned up," as giving no additional useful information.

It is also unfair to compare an average obtained by including all the fish penned up, many of which did not breed, with the total number of ova calculated as being present in one selected large breeder. The comparison can only be fairly made with the eggs in a similar number of Cod, of the same size as those in captivity, chosen at random from the sea. Even in that case the comparison would only indicate whether there was a diminution in the amount of spawn produced per captive fish. There probably is such a diminution; but, on the other hand, it is certain that a large number of possible spawners in the sea are killed by man and other enemies before or during the spawning season.

Then, again, in making a further comparison between artificial hatching and the "processes of nature," it is not right to substitute (p. 41) the number of eggs calculated to be present in the body of a parent for the actual number of eggs treated in the hatchery. This method of "counting the chickens" not only before they are hatched but even before the eggs are laid, is an ingenious method of making the proportion of fry produced in the hatchery seem very small; but I think the Superintendent's figure, 54.6 per cent. of fry to ova, will commend itself to most people as the correct calculation on the common-sense basis of so many ova supplied and so many fry produced. What would have happened to, say, 100 of the hatchery spawners if they had been left in the sea, no one can say. How many of them would live to spawn and how much spawn they would produce we do not know. The percentage of fry to parent fish in the hatchery may, under

some circumstances, be small, but it may be smaller still in a state of nature.

It is curious how Mr. Fryer entirely ignores that side of the question—the destruction in nature. He makes a great point of the mortality in artificial operations, and virtually assumes that in the sea every egg in every fish will be spawned and will then hatch out. This is entirely contrary to the experience of naturalists. In addition to the destruction of the parents in the sea, and the risks of non-fertilisation, and of being cast ashore, we find at the spawning season nearly everything that has a mouth (such as *Medusæ*, *Sagitta*, *Copepoda*, and many fishes) feeding upon fish eggs. One of the strongest arguments in favour of the hatchery is that it protects the embryos from their natural enemies. Judging from the apparently stationary condition of the fish population in the sea, from the enormous numbers of eggs produced, and from our observations on the contents of fishes' stomachs, it is obvious that there must be a very great destruction of eggs, and embryos and larvæ under natural conditions—probably much greater than anything known in artificial operations.

Moreover, in talking (as many do) of the small scale of man's hatching work compared with what takes place in the sea, we do not sufficiently realise the meaning of what is called "the balance of nature." Millions of millions of young are produced and these same millions of millions are destroyed by natural causes, with the result that the species remains fairly constant. If now man disturbs the balance by catching some thousands of the adult fish in a district, he is only equalizing matters and endeavouring to minimise his destructive effect when he adds to that sea-area some millions of artificially hatched fry. And (theoretically at least—probably practically also, for correct

theory and perfect practice must be in accord) he is the better equalizer of the disturbed balance when he uses for the hatchery the eggs of fish which would not have spawned in a state of nature—that he can do by obtaining ripe spawn from the fish trawled for market at the spawning season. This plan has been adopted in some hatcheries; and in our own experiments at Port Erin and at the Piel hatchery. It is the least expensive method of getting spawn, but it is open to several difficulties and objections. The other method is to collect the parent fish beforehand and keep them in ponds until they spawn. It is the method adopted in Norway and to a large extent in the United States, and which Mr. Fryer has tried to show results in a comparatively small number of fry per fish used.

I shall not pursue the matter further. There is no need for me to defend or expound the methods and statistics of the United States Fish Commission. Their own officials are very well able to answer for themselves, and very probably they will do so—if they think it worth while.*

I have merely gone into some of the questions raised in Mr. Fryer's article because it seemed to me that he was modifying the statistics in an unjustifiable manner, and drawing conclusions with which I could not agree, and which might have some bearing upon our procedure in this

* It may be well before leaving this part of the subject to point out that in the appendix (a Manual of Fish-Culture, based on the methods of the United States Commission of Fish and Fisheries, Washington, 1898) to their last published report, which appeared only a few months ago, the United States authorities remark in regard to their artificial propagation of the Cod:—"The unmistakable economic results which have attended these efforts warrant all the time and money devoted to them and justify the greatest possible expansion of the work." I have also more recent letters from the Commissioner and the Naturalists on his Staff making detailed statements to the same effect.

country. We are not, however, in our work here so much concerned with the actual details and difficulties of the American work which Mr. Fryer criticises, as with those general biological principles which I have emphasised above—such as the destruction of young under natural conditions in the sea, and the duty of man if he disturbs the balance of nature in a locality to do what he can to equalize matters by helping in the production and protection of the young.

With Mr. Fryer's remark (foot of p. 41) as to breeding from the larger and more vigorous parents I am in cordial agreement. If aquiculture has been long delayed as a scientific industry, it has as a consequence this advantage, that it can adopt at once principles and practices evolved gradually in the long history of agriculture and stock-raising. It labours, however, under the obvious disadvantage that so much of the result of our labour passes at once beyond our ken. We cannot control the fish throughout their life-history, we cannot yet take stock of the population of our seas. This introduces such an element of uncertainty into the problem, that, although I think we have good reason to be encouraged and to continue the work vigorously in a hopeful spirit and with an open mind, still I for one would not go so far as to say (as some have done) that marine fish-hatching had passed beyond the experimental stage; and I may refer in this connection to the somewhat fuller statement on the subject I made in last year's report,* and to my discussion there of the conditions of a crucial experiment for the purpose of testing the results of adding artificially hatched fry to the population of a circumscribed sea-area. We await with interest the result of the Fishery Board for Scotland's work in Loch Fyne.

* Report for 1897, pp. 24 and 25.

I cannot do better than conclude this section by quoting a couple of sentences from a letter received during the year from Professor M'Intosh, whom we regard as the pioneer of scientific fisheries work in this country. In speaking of marine hatcheries, he says:—"Of course such institutions are strictly experimental, and it may be some time before a decisive result is evident. Meanwhile, work them thoroughly and support them liberally." I desire to endorse that opinion.

OYSTERS AND DISEASE.

(W. A. HERDMAN.)

In collaboration with my colleagues, Professor Boyce (Bacteriologist) and Dr. C. Kohn (Chemist), I have been working at this subject in our laboratories at University College, Liverpool, for the last three years, and interim reports upon the progress of the work have appeared in our three last Fisheries Laboratory Reports. A detailed paper, giving the full results of the investigation, has lately been laid before the Royal Society of London, and the main conclusions of that paper are as follows* :—

"1. Although our primary object was to study the Oyster under unhealthy conditions, in order to elucidate its supposed connection with infective disease, we found it necessary to study in minute detail the histology of certain parts of the body, especially the gills and mantle lobes, the alimentary canal and liver. We give figures and descriptions of these structures in both normal and abnormal conditions.

"2. We have also worked out the distribution and probable function of a minute muscle, which we believe

* Quoted from *Nature* for January 26th, 1899, p. 305.

to be the modified representative of the protractor pedis muscle of some other molluscs.

“3. A diseased condition we found in certain American Oysters very soon brought us into contact with the vexed question of the ‘greening’ of Oysters, and one of the first results we arrived at was that there are *several distinct kinds* of greenness in Oysters. Some of them, such as the green Marennes Oysters, and those of some rivers on the Essex coast, are healthy; while others, such as some Falmouth Oysters, containing copper, and some American Oysters re-bedded on our coast, and which have the pale green ‘leucocytosis’ described in our former paper to the Royal Society, are not in a healthy state.

“4. Some forms of greenness (*e.g.*, the leucocytosis) are certainly associated with the presence of a greatly increased amount of copper in the Oyster, while other forms of greenness (*e.g.*, that of the Marennes Oysters) have no connection with copper, but depend upon the presence of a special pigment, ‘marennin.’

“We are able, in the main, to support Prof. Lankester in his observations on Marennes Oysters; but we regard the wandering amœboid granular cells on the surface of the gills as leucocytes which have escaped from the blood spaces, and have probably assumed a phagocytic function.

“5. We see no reason to think that any iron which may be associated with the marennin in the gills, &c., is taken in through the surface epithelium of the gill and palps, but regard it, like the rest of the iron in the body, as a product of ordinary digestion and absorption in the alimentary canal and liver.

“6. We do not find that there is any excessive amount of iron in the green Marennes Oyster compared with the colourless Oyster, nor do the green parts (gills, palp, &c.) of the Marennes Oyster contain either absolutely or

relatively to the colourless parts (mantle, &c.) more iron than colourless Oysters. We therefore conclude that there is no connection between the green colour of the 'Huîtres de Marennes' and the iron they may contain.

"7. On the other hand, we do find by quantitative analysis that there is more copper in the green American Oyster than in the colourless one; and more proportionately in the greener parts than in those that are less green. We therefore conclude that their green colour is due to copper. We also find a greater quantity of iron in those green American Oysters than in the colourless; but this excess is, proportionately, considerably less than that of the copper.

"8. In the Falmouth Oysters, containing an excessive amount of copper, we find that much of the copper is certainly mechanically attached to the surface of the body, and is in a form insoluble in water, probably as a basic carbonate. In addition to this, however, the Falmouth Oyster may contain a much larger amount of copper in its tissues than does the normal colourless Oyster. In these Falmouth Oysters the cause of the green colour may be the same as in the green American Oyster.

"9. By treating sections of diseased American Oysters under the microscope with potassium ferrocyanide and various other reagents, we find that the copper reactions correspond in distribution with the green coloration; and we find, moreover, from these micro-chemical observations that the copper is situated in the blood-cells or leucocytes, which are greatly increased in number. This condition may be described as a green leucocytosis, in which copper in notable amount is stored up in the leucocytes.

"10. We find that an aqueous solution of pure hæmatoxylin is an extremely delicate test for copper, just as Macallum found it to be for iron.

"11. Experiments in feeding Oysters with weak solutions of various copper and iron salts gave no definite results, certainly no clear evidence of any absorption of the metals accompanied by 'greening.'

"12. Although we did not find the *Bacillus typhosus* in any Oysters obtained from the sea or from the markets, yet in our experimental Oysters inoculated with typhoid we were able to recover the organism from the body of the Oyster up to the tenth day. We show that the typhoid bacillus does not increase in the body or in the tissues of the Oyster, and our figures indicate that the bacilli perish in the intestine.

"13. Our experiments showed that sea-water was inimical to the growth of the typhoid bacilli. Although their presence was demonstrated in one case on the twenty-first day after addition to the water, still there appeared to be no initial or subsequent multiplication of the bacilli.

"14. In our experiments in washing infected Oysters in a stream of clean sea-water the results were definite and uniform; there was a great diminution or total disappearance of the typhoid bacilli in from one to seven days.

"15. The colon group of bacilli is frequently found in shell-fish as sold in towns, and especially in the Oyster; but we have no evidence that it occurs in mollusca living in pure sea-water. The natural inference that the presence of the colon bacillus invariably indicates sewage contamination must, however, not be considered established without further investigation.

"16. The colon group may be separated into two divisions: (1) those giving the typical reactions of the colon bacillus, and (2) those giving corresponding negative reactions, and so approaching the typhoid type; but in

no case was an organism giving all the reactions of the *B. typhosus* isolated. It ought to be remembered, however, that our samples of Oysters, although of various kinds and from different sources, were in no case, so far as we are aware, derived from a bed known to be contaminated or suspected of typhoid.

"17. We have shown also the frequent occurrence, in various shell-fish from the shops, of anaërobic spore-bearing bacilli giving the characteristics of the *B. enteritidis sporogenes* recently described by Klein.

"18. Consequently, as the result of our investigations, and the consideration of much evidence, both from the Oyster-growers' and the public health officers' point of view, we beg to recommend—

"(a) That the necessary steps should be taken to induce the Oyster trade to remove any possible suspicion of sewage contamination from the beds and layings from which Oysters are supplied to the market. This could obviously be effected in one of two ways, either (1) by restrictive legislation and the licensing of beds only after due inspection by the officials of a Government Department, or (2) by the formation of an association amongst the Oyster-growers and dealers themselves, which should provide for the due periodic examination of the grounds, stores, and stock by independent properly qualified inspectors. Scientific assistance and advice given by such independent inspectors would go far to improve the condition of the Oyster beds and layings, to re-assure the public, and to elevate the Oyster industry to the important position which it should occupy.

"(b) Oysters imported from abroad (Holland, France, or America) should be consigned to a member

of the 'Oyster Association,' who should be compelled by the regulations to have his foreign Oysters as carefully inspected and certified as those from his home layings. A large proportion of the imported Oysters are, however, deposited in our waters for such a period before going to market that the fact of their having originally come from abroad may be ignored. If this period of quarantine were imposed upon all foreign Oysters a great part of the difficulty as to inspection and certification would be removed.

"(c) The grounds from which Mussels, Cockles, Periwinkles are gathered should be periodically examined by scientific inspectors in the same manner as the Oyster beds. The duty of providing for this inspection might well, we suggest, be assumed by the various Sea-Fisheries Committees around the coast."

NOTE ON OCCURRENCE OF IRON AND COPPER IN OYSTERS.*

By CHARLES A. KOHN, B.Sc., Ph.D.

'The investigations of Professors Herdman and Boyce on the life conditions of Oysters, which have been in progress since 1895, have pointed to the desirability of ascertaining the quantities of iron and of copper they may contain under either normal or abnormal conditions.

'Two points of interest have arisen in this connection. In the first place the relation of iron to the greenness of the healthy French Oyster (*Huitre de Marennes*); and secondly, the extent to which copper is responsible for the pale green colour of American and other Oysters, a diseased condition accompanied by a leucocytosis discovered and especially studied by Herdman and Boyce. The presence of minute quantities of copper and of iron

* Quote from Report of Oyster Committee to Brit. Assoc., 1898.

as normal constituents of all Oysters has been shown by the analytical data obtained.

‘The results recorded have been made at Professor Herdman’s request, and have proceeded side by side with his investigations. Now that these are completed, a summary of the work from a more purely chemical standpoint may be of interest, especially since the occurrence of these metals—copper and iron—either from the point of view of the origin of colouration or the cause of poisoning has from time to time been the subject of discussion.

‘The Analytical Method Employed.—Electrolytic methods of analysis were adopted both for the determination of iron and copper: these methods, I have already shown,* possess marked advantages for the estimation of minute quantities of metal, especially if derived from organic matter, for they are quite free from any prejudicial influences traces of organic matter may exert, such as arise when volumetric or colorimetric methods are employed. In each determination the bodies or gills only of six or more Oysters were carefully washed, dried between filter paper to remove as much adherent moisture as possible, and then carefully dried in porcelain dishes in the air bath at 100° C. When this drying was as complete as possible, the Oysters were heated in the air bath until thoroughly carbonised, the carbon carefully burnt off over the free flame, and the residue finally ignited in a porcelain crucible. Special care was taken to exclude dust during both the drying and the ignition. The ash was then thoroughly extracted with a mixture of 25 c.c. hydrochloric acid and 25 c.c. sulphuric acid (1 : 2) on the water bath, and the resulting solution filtered and

* Brit. Assoc. Rep., 1893, p. 726.

concentrated. The residue was free from both copper and iron. The acid solution obtained was electrolysed for copper with the usual precautions, a spiral of fine platinum wire weighing about 5 grme. being employed as the cathode. The iron was determined in the residual solution, after neutralisation with ammonium hydrate, &c., acidifying with a few drops of oxalic acid solution, and boiling with ammonium oxalate: 4 grme. of the oxalate were added in each case, the precipitated calcium oxalate (which is quite free from iron) filtered off and thoroughly washed and the resulting solution electrolysed, the metallic iron being also deposited on a spiral of platinum wire. A blank experiment with all the reagents employed was made, and the amount of metal found (0.002 grme. iron) deducted in each case. Also the deposited metal, both iron and copper, was dissolved off the electrode by acid, the solution obtained tested by the ordinary reagents and the spiral re-weighed, as a check upon the determinations, since the quantities found were extremely small.

'The Green Colour of French Oysters, "Huitres de Marennes," and the Presence of Iron in Oysters.—The early observations of Dumas (1841) and of Berthelot (1855) showed that the green colour of "Huitres de Marennes" is not due to chlorophyll, and that although every Oyster contains a certain very small amount of copper in its blood in the form of "hæmocyanin," as determined by Fredericq, the green colour of the French cultivated Oyster is not due to this metal. Ray Lankester* in 1886 confirmed the latter statement, and states in his investigation on the histological condition of the colour that there is neither copper nor iron in the refractory blue pigment "marennin" of the coloured portions of the

* Quart. Journ. Micros. Sci., 1886, 26, 71.

Oyster. Berthelot, however, suggested that the green colour was due to iron, and more recently Chatin and Muntz† have extended and corroborated this statement.

‘From their analytical results these observers conclude that both the green and the brown colourations of various types of French Oysters are due to the presence of iron, and that the depth of colour bears a close proportion to the quantity of iron contained. The colourations are chiefly apparent in the gills, but extend also to the labial palps and parts of the alimentary canal. Chatin and Muntz base their conclusions in the first place upon the fact that they find considerably more iron in the gills than the rest of the body of green Oysters; and secondly, upon the occurrence of a larger quantity of iron in the gills of green than of white Oysters.

‘Appended are some of their results, to which I have added a column, showing the ratio of the iron in the body, minus gills, to that contained in the gills.

Oyster.	Colour.	Iron per 100 parts of dried organic matter.		Ratio of II. : I.
		I. Gills.	II. Rest of body.	
Cancale	White	0·0379	0·0241	1·57
Arcachon	Pale green	0·0605	0·0357	1·69
Marennes	Very green	0·0702	0·0318	1·21
Cancale	Brown green	0·0804	0·0476	1·69
Sables d'Olonnes ...	Very dark brown green	0·0833	0·0436	1·91

‘The relative proportion of iron in the gills hardly bears out the conclusions arrived at; it is the same in pale-green and brown-green Oysters, and in both, but little greater than in the white. On the other hand, the total

† Compt. Rend., 1892, 118, 17 and 56.

iron, both in the gills and in the rest of the body, shows a marked increase, apparently corresponding to the depth of the colouration. The iron was determined in these experiments by potassium permanganate, but the absolute quantities of metal found are not stated. The calculation of the results per 100 parts of dried organic matter is apt to be misleading. In my own experiments it was not found possible to get anything approaching constant weights in this way, and the results are entirely out of accord with those of Chatin and Muntz.

'The following table gives the quantities of iron found in French as compared with American Oysters, three pairs of gills being analysed in each case.

'These figures show conclusively that there is more and not less iron in the gills of the white American Oysters than in the French, and this irrespective of the basis on which the result is calculated. The ash is undoubtedly the most reliable factor to calculate on, provided the Oysters are carefully washed before drying, which was always done: the result per pair of gills (or Oyster) is most in accord with this, and has the advantage of being an easy and in many respects useful basis.

	Huitres de Marennes.	American.
Gross body weight, after drying between filter paper	3·8 grms.	6·5 grms.
Weight dried at 100° C. for six hours	0·52 "	1·02 "
Weight of ash	0·0940 "	0·1140 "
Weight of <i>Iron</i> found	0·0003 "	0·0008 "
<i>Ratio of Iron found:—</i>		
(1) Calculated per pair of gills	1 to	2·7
(2) " on gross body weight... ..	1 to	1·56
(3) " at weight at 100° C.	1 to	1·36
(4) " on ash	1 to	2·2

‘The relative quantities of iron present in the gills as compared with the rest of the body were next determined in French, Dutch, and American Oysters. Six Oysters, or the gills of six Oysters, were analysed in each case with the following results:—

Six Oysters.	Weight of Iron found in mgrme.		
	French.	Dutch.	American.
Gills	0·6	0·4	2·3
Bodies minus gills	1·2	1·5	1·7
Weight of ash of gills	0·1880	0·0217	0·0294
„ „ of bodies minus gills ...	0·5980	0·1125	0·1240
% Iron on ash. Gills	0·32	1·85	7·82
„ „ Bodies minus gills ...	0·20	1·33	1·37
<i>Ratio of Iron in gills to Iron in rest of body.</i>			
Calculated per Oyster	1 : 2	1 : 3·75	1 : 0·74
„ on ash	1·6 : 1	1 : 4·1	5·7 : 1

‘From these figures it is evident that the gills of the French Oysters do not contain an excessive quantity of iron such as might account for their colour. Calculated per Oyster the gills contain less iron than the rest of the body, except in the American Oyster; calculated as a percentage on the ash the reverse is the case. The proportionate quantity of iron in the gills as compared with the rest of the body is somewhat greater in the French Oysters than in the Dutch, but much less than in the American.

‘Clearly, therefore, there is no connection between the green colour and the quantity of iron present. This result is quite in accord with Ray Lankester’s observation that his “marenuiin” is free from iron as well as from copper.

‘Both the gills and bodies of Oysters contain a small

quantity of iron, which is evidently normally present, the gills containing a somewhat larger amount in proportion to the total quantity of mineral matter present.

‘Finally, the total iron in a variety of Oysters was determined in order to ascertain the normal quantity present. These data, which are tabulated below, show a fairly constant proportion of iron per Oyster, from 0·15 to 0·36 mgrme., or from 0·18 to 0·65 per cent. on the ash.

Total Iron present in Oysters.

Variety of Oyster	Number Analysed.	Total Iron grme.	Weight of Ash.	Mgrme. Iron per Oyster.	Percent- age of Iron on Ash.
‘Hutres de Mar- rennes’	6	0·0018	0·7860	0·30	0·23
Dutch	6	0·0009	0·1393	0·15	0·65
American	5	0·0018	0·2791	0·36	0·64
Colne	10	0·0020	1·0938	0·20	0·18
Deep Sea	2	0·0064	1·5017	0·32	0·43
Falmouth	6	0·0016	0·4534	0·27	0·35

‘In considering the variations in quantity, the very small amounts of metal present must be borne in mind.

‘It may be added that although Carazzi has attributed the green colour of French Oysters to iron taken up from the mud of the Oyster-park or “*claire*,” experiments on feeding Oysters with very dilute solutions of iron salts (0·02 to 0·01 per cent.) carried on in conjunction with Prof. Herdman produced no green colouration whatever. The only result was a certain amount of “browning” throughout the Oyster, the gills being no more affected than the rest of the body. More recently Carazzi has shown that Oysters fed with similar dilute iron solutions acquire a pale yellowish colour in certain parts (branchial epithelium and the œsophageal mucous membrane), and

that in these parts microscopic tests show the presence of granules of iron. The actual meaning of these results can hardly be recognised without quantitative data.

'The Presence of Copper in Oysters.—Fredericq has shown that a certain small amount of copper is present normally in the hæmocyanin of the blood of crustaceans and molluscs. The quantity thus present in Oysters of different origin is fairly constant as shown in the following table: it varies from 0·25 to 0·66 mgrme. per Oyster, or from 0·30 to 1·18 per cent. on the ash.

Variety of Oyster.	Number Analysed.	Total Copper grme.	Weight of Ash.	Mgrme. Copper per Oyster.	Percent- age Copper on Ash.
'Huîtres de Mar- rennes'	6	0·0024	0·7860	0·40	0·30
Dutch	6	0·0015	0·1393	0·25	1·08
American	5	0·0033	0·2791	0·66	1·18
Cologne	10	0·0036	1·0938	0·36	0·33
Deep Sea	2	0·0069	1·5017	0·34	0·46

0·4 mgrme. per oyster may be taken as an average, a quantity slightly greater than the average iron (0·26 mgrme.). The calculated percentages on the ash show greater variations, due to the very considerable differences in the total quantities of mineral salts present, and it is probably to this last factor that the popularly recorded differences in taste of the various kinds of oysters is really due. Certainly the minute quantities of copper and iron present cannot account for them.

'The copper was also determined in the gills and in the bodies minus gills of French, Dutch, and American Oysters, with the following results:—

Determination of Copper.

Six Oysters.	French 'Huitres de Marennes.'	Dutch.	American.
Gills only	Trace	0·8	1·7
Bodies minus gills...	1·4 mgrme.	1·4	3·3

'These data show conclusively that the green colour of the gills of French Oysters is also in no way connected with the copper present.

'Quantities of copper greater than those recorded point to abnormal conditions. Such have been found to occur with certain Falmouth Oysters, and in an especially interesting manner with the green leucocytosis of American and Falmouth Oysters—the diseased condition referred to above.

'*Falmouth Oysters.*—The presence of relatively large quantities of copper in Falmouth and other Cornish Oysters has been repeatedly associated with their bluish-green colour. Dr. T. E. Thorpe* states that these Oysters, the colour of which, both in character and distribution, is quite different from that of the Marennes Oysters, contain on the average about 1·3 mgrme. of copper per Oyster. This large proportion is, Dr. Thorpe says, "obviously caused by the mechanical retention of cupriforous particles." On relaying they lose their colour, and the quantity of copper present becomes normal, 0·4 mgrme. per Oyster.

'Six Falmouth Oysters, the bodies of two of which were of a distinct arsenic-green colour, were dried at 100° C., and then digested with water and subsequently with dilute hydrochloric acid. The extract contained about half the total copper present, showing that the metal is partially,

* "Nature," 1896, p. 107.

at any rate, mechanically retained on, or in the body of the Oyster, probably as a basic carbonate.

‘The analytical results were as follows:—

Six Oysters.	Cop- per.	Iron.	Wght. of Ash.	Mgrme. Copper per Oyster.	Mgrme. Iron per Oyster.	Per cent. Copper on Ash.	Per cent. Iron on Ash.
Extract with dilute acid ...	0·0097	0·0024	0·2272	1·62	0·40	4·22	1·06
Oysters ...	0·0114	0·0016	0·4534	1·90	0·27	2·51	0·35
Total ...	0·0211	0·0040	0·6806	3·52	0·67	3·10	0·59

‘The total copper present is almost nine times the normal quantity, and about half of this is easily removed by dilute acid. It is quite likely that the remainder is partially or wholly simply entangled in the food passages of the Oyster, and that the green colour may be due to some other cause than this mechanically retained copper, as suggested by Herdman.* Mr. G. C. Bourne, indeed, regards it as due, in some Falmouth Oysters, to a green desmid upon which the Oysters feed in quantity.

‘The occurrence of copper under such conditions is due to the locality, and may quite possibly attain injurious proportions, for the Oysters were obtained from a creek which is locally supposed to bring down copper, and the mud of which was found by Thorpe to contain 0·148 per cent. of copper. Normal sea-water contains such an excessively small quantity of copper that it was not found possible to detect its presence, even electrolytically, in a litre of sea-water, after concentration.

‘The *green leucocytosis* already referred to was first noticed by Herdman and Boyce in American Oysters

* “Nature,” 1897, p. 366.

which had been relaid near Fleetwood. The colour manifests itself in patches and streaks of pale green on the mantle, in engorgements of the blood vessels and in masses of green coloured leucocytes in the heart. The leucocytes are apparently all amœboid wandering cells, comparable to the colourless corpuscles of the blood of higher animals, and the colouration coincides with their distribution.

‘ The six greenest and six whitest of 120 of these Oysters were chosen for analysis ; also a quantity of the greenest portions of the greenest Oysters was selected from another batch, and compared with the corresponding portions of the whitest Oysters. The iron was not determined in the latter comparison, owing to contamination of metal in cutting.

‘ The following were the results obtained :—

Oysters.	Cop- per.	Iron.	Ash.	Mgrme. Copper per Oyster.	Mgrme. Iron per Oyster.	Per cent. Copper on Ash.	Per cent. Iron on Ash.
Green ...	0·0158	0·0091	1·1450	2·63	1·52	1·38	0·79
White ...	0·0042	0·0036	1·0948	0·70	0·60	0·38	0·33
Greenest parts	0·0033	—	0·0780	—	—	4·23	—
Whitest parts	0·0009	—	0·0452	—	—	1·99	—

‘ The excessive quantity of copper in the selected green Oysters is 3·75 times that in the white calculated per Oyster, and 3·63 times calculated on the ash. In the selected parts the total copper present calculated on the ash is high in both cases, and the green parts again show a marked excess in the proportion of 2·1 to 1. The copper and iron in the white specimens are about normal, but the increased quantity of iron in the green is marked, being 2·5 times that of the former. Still there is relatively

a large excess of copper as compared with iron in the green Oyster, as is evident from the analyses, the ratio being 1·1 : 1 for the white and 1·8 : 1 for the green.

‘It is to be concluded, therefore, that the green colour of these Oysters is coincident with the distribution of the excessive quantity of copper present, and that the copper is in consequence to be regarded as the cause of the colour. The histo-chemical investigations of Boyce and Herdman have amply confirmed this conclusion.

‘Further, this leucocytosis is not accompanied by a mere redistribution of copper, but by an absolute increase of the amount present in the body.

‘The deposition of copper in this manner is regarded by Boyce and Herdman “as a degenerative reaction, due to a disturbed metabolism, whereby the normal copper of the hæmocyanin, which is probably passing through the body in minute amounts, ceases to be removed, and so becomes stored up in certain cells.” The change is comparable in kind to the accumulation of iron in pernicious anæmia.

‘The increased quantity of iron present may also be due to abnormal conditions of life, but a more accurate localisation of the normal iron of the Oyster is necessary before this can be decided.

‘This green leucocytosis has been observed by Herdman and Boyce in other Oysters, including those of Falmouth, and it is likely to be the real cause of their colour; a colour therefore due to copper as previously supposed, but accompanied by a diseased condition. Whether the presence of copper in the water facilitates in any way the development of the disease has not been determined; experiments made on keeping Oysters in very dilute saline copper solutions give no affirmative results beyond a certain amount of post-mortem green staining.

'*Manganese* was found to be present in several of the varieties of Oysters analysed. Its detection is readily effected in the electrolytic method of analysis as it separates at the anode as peroxide. Colne Oysters contained 0.14 mgrme. per Oyster—a rather smaller quantity than the iron found.'

MUSSEL-BEDS AND MUD-BANKS.

By R. L. ASCROFT.

On the Lancashire and Cheshire coasts it is often noticed that Mussel-beds are situated on banks of mud. Mussels require, in the earliest shelled stage, some hard substance to attach themselves to, such as stone, gravel, hardened sand (such as *Sabellaria* tubes, for instance), shells, such as Cockles or Mussels, wooden piles, and the bottoms of boats. As they grow up and increase in size (when located where there is little wave action), through their excreta and the mud settling amongst them they are inconvenienced, and to escape being buried a lengthening of their cables, or byssus, takes place, and so they lift themselves. This process, repeated time after time, raises the Mussels a great height above their original location, and the bed of mud increases accordingly.

The greatest depth that I have heard of occurred in the River Ribble, where a bed of gravel was bare in the channel a little above Lytham, when a strike of Mussels occurred on it, and in the course of three years the Mussels accumulated a bank of mud ten feet in depth—there being no wave action to affect it.

At St. Amnes-on-the-Sea, below the pier, there is a bed of gravel on which a strike of Mussels occurs every two years. During the two years growth the mud gets to a

depth of two feet, and then the heavy seas reach the bed and roll the Mussels off like a carpet, and I have seen them strewn along the beach at high-water mark as far as Lytham Pier, a distance of four miles, during the same tide.

Under the refreshment rooms at Southport Pier is a foundation composed of stone on which Mussels strike. They then accumulate mud until their cables, or byssus, reaching down to the stones, get too weak, and they are then washed away. The same thing occurs in the Rock Channel, and on the great scars at Heysham.

In the case of St. Annes, and doubtless in the other cases also, if the seaward edge of the scar was protected by piles or posts, and the Mussels so rendered less liable to be broken into by the sea, they would then, in all probability, be able to grow to a marketable size.

The researches of Mons. Viallanes at Arcachon, in the South of France, have proved the power of Mussels in comparison with Oysters to separate food and refuse (sand, &c.) from the water. By his experiments he shows that for one quart of water filtered by a French or native Oyster 18 months old, a Portuguese Oyster of the same age filtered $5\frac{1}{2}$ quarts, and a middle-sized Mussel 3 quarts. The excreta respectively were 0.199 gramme, 1.075 grammes, and 1.768 grammes per 24 hours. So that in proportion to the numbers covering the same area of ground the Mussel will deposit three times as much material as a Portuguese, and eighteen times as much as a French or native Oyster.

There is no doubt but that the rate of growth is to a great extent proportional to the food consumed, so that it is clear that the Mussel has a much greater quickness of growth than a native Oyster.

The accumulation of mud (other conditions being the

same) is much greater where brackish water flows at times over the bed, and it is a well known fact that Mussels in such a place thrive and grow much more quickly than those in pure sea water, no doubt through the large quantity of food brought down by the rivers. So much is this the case that every year Mussels are removed from the scars on the seaward side of the River Wyre below Fleetwood and placed in the same river above Fleetwood to have the benefit of the brackish water.

The number of young Mussels (eggs and embryos) given off by their parents must be in quantity simply enormous. At Southport during the autumn, if a rope's end is allowed to hang in the water for the space of a month you find it at the end of that time coated with Mussels, like a swarm of bees hanging on a bough.

Boats, buoys, and all wrecks or posts near low-water mark are smothered with them. These objects form natural bouchots from which the young Mussels might well be removed for cultivation elsewhere.

REPORT ON THE PHYSIOLOGY OF COLOUR-CHANGE IN HIPPOLYTE AND OTHER MARINE CRUSTACEA.

By F. W. KEEBLE, M.A., and F. W. GAMBLE, M.Sc.,
Owens College, Manchester.

By the recommendation of Prof. Herdman and the permission of the Lancashire Sea-Fisheries Committee, we were allowed to utilise the Piel Laboratory for the purpose of investigating the colour-physiology of *Hippolyte varians*. We paid two short visits (from May 27th to 30th, and July 1st to 5th) in order to ascertain the resources of the Laboratory and to discover the localities in which *Hippolyte* could be obtained. As these

visits were successful, it was decided to spend the long vacation at Piel, and accordingly the work was started on July 15th and carried on without interruption till Sept. 22nd., concluding with a visit Dec. 15-22. In the present Report we merely give a short account of the methods employed, since the results obtained by their means are not yet ready for publication.

Hippolyte varians is one of the few Crustacea which may be considered abundant in the neighbourhood of Piel. It keeps, for the most part, to beds of weeds below low-water mark, and hence its habits have largely to be learnt from specimens in captivity. Compared with its associates—*Idothea*, *Mysis*, and *Crangon*—*Hippolyte* is of a delicate constitution, and needs constant aëration or constant change of sea-water to maintain it in good health. The resources of the tank-room at Piel enabled us to overcome this difficulty. Fresh weed or the dead bodies of its fellows serve *Hippolyte* as food. With due precautions specimens may be kept under observation for ten days or a fortnight.

From the nature of the beds of sea-weed in the Barrow Channel a haul with weighted canvas tow-nets usually contains an assortment of *Hippolyte* of different sizes and colours. Shades of brown and yellow are abundant, whilst green and red are sometimes common, sometimes rare. With the large *Halidrys siliquosa* a dark brown variety is associated; among the fine Polyzoon (*Bowerbankia*) which clothes the lower parts of the *Halidrys* stems, a speckled variety of *Hippolyte* occurs: in the tide-pools of Foulney Island the green variety, and it alone, is found among the *Zostera*.

The methods employed for investigating whether there is a power of colour-change, and if so, how this power may be tested, were for the most part quite simple. One

method consisted in testing the effect of light of differing intensities upon a given variety. To do this a number of jars, some of clear glass, others enveloped with muslin, others again with black cloth, were taken on board, and as soon as the nets were hauled up, the *Hippolyte* were recorded, and specimens of each variety were placed in each jar. The effects produced differed very markedly according to the time of day at which the catch was made; the result of treating a haul in this way after dark or even in waning light being very different from that obtained at mid-day.

We also directed our attention to the influence of variously coloured weeds, with the object of testing whether a brown *Hippolyte* would become green when placed with green weeds, and red when surrounded with red ones. For this purpose we had devised an apparatus which was described shortly before the British Association at Bristol.

This instrument consists of a "pressure-bottle," holding a couple of gallons of sea-water, which is discharged at a uniform rate through an escape-tube commencing with a minute opening. The water is made to circulate through a series of air-tight observation-dishes, in which the *Hippolyte* are placed. The loss of water from the pressure-bottle is made good by the entrance of air which is first drawn through a second series of observation-dishes, the water in which is changed once or twice a day only. On the whole it was found that *Hippolyte* flourishes best in the air-circulating dishes.

The influence of monochromatic light was investigated by the aid of Landolt's fluid "colour-filters." In order that the light which reaches *Hippolyte* may be of fairly high intensity and not merely equivalent to shade, we employed a mirror to reflect sunlight or the light of an

incandescent lamp into the jars which were otherwise quite opaque.

The effects of direct sunlight, reflected light and scattered light upon the colour of *Hippolyte* were tested by exposing carefully recorded specimens to these influences in the open grassy space outside the Laboratory. To prevent a rise of temperature in the sea-water, we employed a circulation of water derived from the supply in the Laboratory to flow through our observation-dishes. The methods we used for investigating the effects of rise and fall of temperature, electrical stimulus and of toxic agents do not call for remark here. At night and often during the day the records (chiefly microscopical) were made by the light of an incandescent lamp.

We have arrived at the conclusion that there are two colour-phases in *Hippolyte varians*; one diurnal, the other nocturnal. The recurrence of these phases is to some extent independent of the conditions of illumination, although the colour itself may be profoundly influenced by varying the quality and intensity of the incident light, and also by other stimuli, which do not act through the eye.

The advantages which the Piel Laboratory affords for work of this kind are very considerable, and while expressing our thanks to Professor Herdman and to the Curator of the Laboratory (Mr. Andrew Scott), we wish to acknowledge our marked indebtedness to the Lancashire Sea-Fisheries Committee for the generous help which is afforded by them for the prosecution of scientific work, generosity which will surely become more widely appreciated as it becomes more generally known.

ADDENDUM.

The species of Crustacea we worked with, have been kindly identified by A. O. Walker, Esq. From the very limited fauna of Piel shore, it may be of interest to give the list, which, however, is not quite complete.

Hippolyte varians, Leach, common, just below the level of ordinary spring tides.

Hippolyte fascigera, Gosse, a doubtful species.

Almost certainly a variety of *H. varians*.

<i>Hippolyte cranchii</i> , Leach.	} Less common but occurring with the foregoing.
<i>Hippolyte pusiola</i> , Kröyer.	

A species of *Mysis* which gave interesting results and which occurs with *Hippolyte* has been determined as *Mysis neglecta*, G. O. Sars.

A small collection of Pycnogonida, which have no connection with the present research but which were taken among the fine red weeds of the Barrow Channel, contains the following forms:—

Ammonothea echinata, Hodge.

Anoplodactylus petiolatus (Kröyer).

Pallene brevirostris, Johnst.

Nymphon gracile, Leach.

APPENDIX.

LANCASHIRE SEA-FISHERIES HATCHERY
AND LABORATORY AT PIEL.

REGULATIONS IN REGARD TO WORKERS.

1°. Biologists and Students desiring to work at the Piel Hatchery should apply to the Hon. Director (Professor Herdman) who, if there is room, will allot them work places in the Laboratory in the order of application.

2°. In the absence of the Director, the Resident Assistant (Mr. Andrew Scott) will determine which places in the Laboratory workers are to occupy, and to what extent the instruments of the Laboratory (microscopes, microtomes, &c.), and the boats and collecting apparatus may be used by workers.

3°. The Aquaria in the tank house are intended for experiments in Fish Hatching and Fish Rearing, and it is only by express permission of the Director or the Resident Assistant that they may be used for private investigations.

4°. Laboratory accommodation and lodging in the house are given free of charge to those duly qualified workers or students whose applications have been accepted, and who have been assigned places in the Laboratory. Meals (breakfast, dinner, tea and supper) are provided for those working in the Hatchery at a fixed charge of 3s. per day or 15s. per week, payable to Mr. Scott.

5°. The Resident Assistant will be ready to give assistance to workers at the Hatchery, and to provide them with material for their investigations so far as it does not interfere with his routine duties and his "fisheries" work.

6°. All dishes, jars, bottles, tubes and other vessels in the Laboratory may be used freely, but must not be taken away from the Laboratory. If any workers desire to make, preserve and take away collections of marine animals and plants, they must provide their own bottles and preservatives for the purpose.

7°. The fish and other specimens in the tank room are the property of the Institution and must not be used or disturbed by workers in the Laboratory.

8°. Each worker in the Laboratory is required to send a short account of his work done at the Institution, and of the results he has attained, to the Director before the 1st of December (at latest), in order that it may be entered in the Annual Report to the Sea-Fisheries Committee.

W. A. HERDMAN,

*Honorary Director of the Scientific Work
to the Lancashire Sea-Fisheries
Committee.*

NOTE on MID-WINTER SURFACE and DEEP
TOW-NETTINGS in the IRISH SEA.

By ISAAC C. THOMPSON, F.L.S.

[Read March 17th, 1899.]

TAKING advantage of a fine day and smooth sea, after a month of abnormally boisterous weather round our coasts, on January 29th, 1899, I accompanied Mr. Dawson, Superintendent of the Lancashire Fisheries, and Prof. Herdman, on an inspection of the spawning grounds off the west of the Isle of Man, in the fishery steamer "John Fell." In addition to the apparatus and trawls used on board the steamer, we were provided with dredges and tow-nets belonging to the Port Erin Biological Station, our point of departure.

Gradually steaming up the western side of the Island, when several hauls of the tow-nets and dredge were made, it was thought by our scientific expert to be an excellent opportunity for noting, on a typical winter's day, both the quantity and comparative character of the plankton collected, under similar conditions, at the surface and at the sea bottom.

The vertical, no less than the horizontal and seasonal distribution of the Copepoda, must be of considerable importance in connection with their value as fish food. Some species, such as *Temora longicornis*, appear to live only at or near the surface, while others, like *Euchaeta norvegica*, are seldom found in less than 100 fathoms in depth. Some species evidently have a vertical migration, though what is the positive reason for this it would be difficult to answer. Light appears, in some cases, to act

as an attractive influence, in others as a repellant; and it is not improbable, as evidence seems to favour, that different intensities or kinds of light, whether as sunlight, moonlight, or electric light, have various degrees of attractive or repelling power.

At a depth of 33 fathoms, when about six miles west of Peel, a cast of the steamer's large trawl was made, a finely-meshed tow-net being fixed to the line at about 3 fathoms distance from the trawl. As the vessel slowly proceeded the tow-net would be within a varying few feet from the sea bottom. Simultaneously a similar tow-net was let out at the stern of the ship, and allowed to run at the surface and to within a few feet thereof.

The temperature of the surface water was about 44° Fahr., and only a slight ripple on the sea, and a cloudy sky without sunshine.

Experience has often annoyingly shown us the great risk to which a bottom tow-net, attached to a trawl or dredge, is exposed from its passing over rough ground, the tow-net frequently being either bodily carried away or torn in such a way that the entire contents have escaped. It was, therefore, with much satisfaction that on this occasion when the trawl was hauled up after $1\frac{1}{4}$ hours immersion, the vessel steaming very slowly meantime, although the trawl-net itself was torn, the tow-net was found to be in perfect condition, and containing a considerable quantity of living plankton.

At the same moment the surface net was taken in, and the contents of each net were immediately preserved in bottles containing a 5 % solution of Formol and sea-water.

The following table is a summary of the respective contents, Copepoda forming, as might be expected, by far the largest proportion of each.

Allowing the contents time to sink the amount of

surface material was found to be 8 cc., that taken by the bottom tow-net 20 cc., showing the latter to be $2\frac{1}{2}$ times as much in quantity as the former.

TABLE showing Plankton taken by surface and bottom (33 faths.) tow-nets, January 29th, 1899:—

		Surf. Towntet	Bot. Towntet
Copepoda.	<i>Calanus finmarchicus</i> - - -	F	A
	<i>Pseudocalanus elongatus</i> - -	A	A
	<i>Bradyidius armatus</i> - - - -		S
	<i>Centropages hamatus</i> - - -	C	
	<i>Temora longicornis</i> - - - -	F	
	<i>Metridia longa</i> - - - - -		F
	<i>Acartia clausii</i> - - - - -	A	C
	<i>Candace pectinata</i> - - - -		F
	<i>Oithona spinifrons</i> - - - -	C	F
	<i>Euterte acutifrons</i> - - - -	C	
	<i>Longipedia coronata</i> - - -	S	
	Diatomaceæ - - - - -	A	S
	Foraminifera - - - - -	F	
	Medusæ - - - - -	F	
	Ctenophora. <i>Pleurobrachia</i> -		F
	Chætognathæ. <i>Sagitta</i> - -		A
	Crustacea, Amphipoda - - -		F
	„ larval Cirripedes -	F	
	„ „ Schizopods -	F	C
	Mollusca, larval - - - - -	F	
	Fish ova - - - - -		F
	Annelids, larval - - - - -	F	F

A=abundant. C=common. F=few. S=scarce.

An analysis of the above table shows that four species of Copepoda were common to surface and bottom, viz., *Calanus finmarchicus*, *Pseudocalanus elongatus*, *Acartia clausii*, and *Oithona spinifrons*. In proportion to the

amount of plankton in each tow-net, *Calanus finmarchicus* was far more abundant at the bottom than at the surface, the preponderance of males being very marked. *Pseudocalanus elongatus* was very abundant in both tow-nets, the number of specimens in the lower one being equal to that of all the other species put together.

Acartia clausii and *Oithona spinifrons* were in about equal proportions; more plentiful in the surface net than in the bottom net, but few specimens of *Oithona* being found in the latter.

Four species of Copepoda were found in the surface tow-net only, viz., *Temora longicornis*, *Centropages hamatus*, *Longipedia coronata*, and *Euterpe acutifrons*. The two first-named are very common British species, being rarely found at any distance below the surface.

Longipedia coronata is also common, though usually found in rocky pools attached to fuci, between tidal limits. The occurrence of *Euterpe acutifrons* in considerable quantity is rather surprising, inasmuch as it is a rare species round our coasts, and seldom found in any quantity.

It is of wide distribution, extending from South America, into the Atlantic, the Canary Islands, throughout the Mediterranean, the northern coasts of France, and at Heligoland.

Three free-swimming species, not occurring in the surface tow-net, were found in the bottom net, viz., *Bradyidius armatus*, *Metridia longa*, and *Candace pectinata*, the latter being entirely new to the L.M.B.C. district, and the two former seldom met with.

Bradyidius armatus I have found on two or three previous occasions at similar depths. It is readily distinguished from the common *Pseudocalanus elongatus*, from which genus Giesbrecht has lately removed it, by the strong spinous terminations to the cephalothorax.

Metridia longa is decidedly rare in our district. It is a distinctly northern species, having been reported from the Arctic Sea, Greenland, Spitzbergen, Scotland, and as far south as the English Channel, and about the Channel Islands. I have lately found it very plentiful in plankton collected about Valencia, on the West of Ireland, and it was frequently present in the collections taken by Prof. Herdman in his traverse of the North Atlantic.

The finding of several fine specimens of *Candace pectinata*, for the first time in our district, is notable. This species was first found by Drs. Brady and Robertson, at a depth of 40 fathoms, off the Scilly Islands. I have on several occasions found it about the west coast of Scotland, and Mr. Thomas Scott reports it from the Frith of Forth. I found it very sparingly off the Channel Islands, and fairly plentiful about Valencia, Ireland. It thus appears to be probably generally distributed round the British Isles, and both at surface and sea bottom. Dr. Brady reports the "Challenger" captures of this species about Australia, the Phillipine Islands, and between Ascension and the Azores. I found it common about the Canary Islands. It and the other members of the genus *Candace* are at once distinguishable by the dark-coloured antennæ, spines, and plumes, and the terminal spines and the swimming feet.

The surface Diatomaceæ were very numerous, while the very few found in the lower net were probably taken in as it neared the surface. Mr. Thomas Comber, F.L.S., to whom I sent the surface Diatoms for examination, has kindly drawn up the following list of 18 species found, viz.:—

DIATOMS—

Biddulphia mobiliensis, common.

Coscinodiscus concinnus, common.

C. centralis, occasional.

Nitzschia paradoxa, frequent.

Fragilaria hyalina, occasional.

Synedra Gaillonii, occasional.

Thalassiosira Frauenfeldii, occasional.

Eunotia sp., occasional, a fresh-water form.

Rhabdonema adriaticum.

Grammatophora marina.

Navicula gregaria.

Isthmia enervis.

Paralia sulcata.

Cyclotella striata, var. *ambigua*.

Chaetoceros boreale.

C. pelagicum.

C. secundum.

C. fucellatum.

The few Foraminifera found were at or near the surface, as also were the few Medusæ taken.

Several Pleurobrachia were in the bottom net, but none in the surface; and an enormous number of Sagitta were brought from the bottom, but none were found near the surface.

A few fish ova were taken by the bottom net only. The distribution of the remaining plankton taken can be seen from the table (p. 158).

From these comparative results of the gatherings taken from upper and lower strata, it is clear that both should be noted at any given time, as there is much to be yet learned as to the effects of temperature and other influences upon the minute forms of life of our seas. It is hoped that we may be able, say at the four seasons, during the rest of the year, to continue observations on a similar plan.

To obviate the difficulty of arranging a bottom tow-net, there is the alternative method of pumping water directly

up, from any depth, through a hose pipe sunk as low as required, and worked by a hand pump fixed on the steamer's deck, the water then passing through an ordinary fine tow-net. This has been already successfully tried by Dr. Kofoed and others in America, and recently by Mr. Garstang, from Plymouth. A suitable pump and hose has been supplied to the Port Erin Biological Station for use on the next and all future expeditions, when the results will be duly recorded.

SOME SPECULATIONS on the DERIVATION of
our BRITISH COLEOPTERA.

By W. E. SHARP.

[Read January 13th, 1899.]

AMONG the many problems to which the attention of the modern Biologist is invited, that of the present distribution and probable derivation of floras and faunas is one of the most interesting and fascinating—interesting because in the most cursory survey of the subject so many issues are seen at once to be involved; fascinating because so wide a door is thrown open to the most unfettered theorizing, and because in any adequate comprehension of these problems possible answers to so many questions seem to lie hidden—questions propounded by the Geologist not less than by the Biologist.

No one will dispute that this enquiry is a very difficult and perplexing one; that its factors are more than usually complicated and obscure; and that the evidence we have available is, as it affects vast groups of animals, meagre and defective. As Dr. Wallace has well said in a recent work:—

“There is no short and easy method of dealing with these questions (that is, the present distribution of organic life), because they are in their very nature the visible outcome and residual product of the whole past history of the earth. If we take the organic productions of a small island or of any very limited tract of country, such as a moderate sized parish, we have in their relations and affinities—in the fact that they *are there* and others are *not there*—a problem which involves all the migrations of

these species and their ancestral forms—all the vicissitudes of climate and all the changes of sea and land which may have affected these migrations—the whole series of actions and reactions which have determined the preservation of some forms and the extinction of others—in fact, the whole history of the earth, inorganic and organic, throughout a large portion of geological time.”

Now to invite your attention to so vast a subject as this will, I am sure, appear a considerable presumption on my part, and I will hasten to alleviate your apprehensions by saying that my intention is only to consider one order of one class of the British Fauna, and I do this with the more confidence from the fact that of the distribution of the British Coleoptera very little is really known, and of its proximate derivation still less. It therefore appears a safe topic on which to theorize, our ignorance of facts allowing us a more unbiased freedom in speculation. Apart, however, from this rather dubious qualification, to render such an enquiry as this—that is, the distribution and origin of the British Fauna—manageable, it becomes necessary to narrow the question down to one small group of that fauna: one must attack it in detail if one wishes to do so at all exhaustively. Further, it appears to me that the Coleoptera or Beetles afford particularly good material for such an enquiry, and here I am not indeed sure whether it is not perhaps necessary to defend the cause of the terrestrial invertebrate *in limine*, so strong are the traditions of this room in favour of the marine—so permeated is its very atmosphere with “murmurs and scents of the infinite sea.” But it seems obvious that when we come to talk about distribution your student of terrestrial life has most to say. Fresh-water faunas are another matter, but I venture to think that not much as regards past earth movements, submersions and upheavals,

streams of migration and so on, can be deduced from a study of purely pelagic life.

Thrown back, then, on our terrestrial organisms, and leaving out of account the flora which, in many ways, affords better and more abundant evidence than does any part of our fauna, we find the mammals and reptilia far too small in specific numbers to be of much service in the enquiry. There are certainly in the distribution of our fresh-water fishes most valuable and significant facts; but it is to the invertebrates which far out-number all the other organisms put together that we find our most abundant material and safest guides; and of the invertebrates, certainly the insects have been most closely and generally studied, and of them consequently the British distribution is perhaps best known.

The majority of insects however fly, and, of course, the evidence afforded by creatures whose transport is so easy may readily become misleading; but of all the insects the Beetles use their wings least; in fact, some of them do not possess these organs in any effective degree. The Coleoptera too, are exceedingly numerous, both specifically and individually, some 3,300 species being recorded as British, and they are perhaps more uniformly and generally distributed than any other order of insects.

I will therefore invite your attention to what is known, and still more, to what is unknown, of the distribution of the Coleoptera of these islands and their possible derivation, premising only that any inferences we may draw from such facts, unless equally applicable to the distribution of all the other fauna and all the flora as well, are theoretically invalid.

Now the first broad fact to bear in mind is that the whole British Coleopterous Fauna, and, indeed, we might say the whole British Fauna, is simply part and parcel of

that of north-western Europe. It is merely a restricted extension of what is known as the Palæarctic Fauna, possessing, at any rate among the Coleoptera, hardly any distinct forms of specific and very few of even varietal value. I am quite aware in saying this that there are some 67 species out of our British total which so far have not been publicly recorded from any other country. I venture, however, to dismiss these as evidences of any distinct Coleopterous Fauna, because, firstly, the bulk of them are merely of slight varietal value; secondly, they are all exceedingly rare, many resting as unique specimens; and thirdly, because I can recognise no presumption that because they have never been recorded, they therefore necessarily do not occur elsewhere in Europe.

If, then, we seek the phylogenetic origin of our British Beetles, we must find it in the origin of the whole Coleopterous Fauna of the north temperate zone, and here we become at once lost in the dark abyss of Geologic time. We certainly know that insects, as we find them now, are of vast antiquity. As far back at least as the carboniferous forms referable to existing orders appear, while fossil Coleoptera generically allied to present forms have been found in Oolitic and Cretaceous deposits in England. Indeed, it seems safe to assume that the bulk of our present species of insects peopled the England of, at any rate, later Tertiary times. The evidence of this is supplied by Beetle remains, wing cases, and so on, found in the Cromer Forest beds, which can be almost specifically assigned to modern *Harpali* and *Donaciæ*. These beds, I believe, are generally admitted to be, at any rate, ante-glacial, and the remains in them probably represent the late Pleistocene fauna and flora of the British Isles, if you can so term some indefinite extension of north-western Europe, of whose configuration and limits we can only

vaguely guess. Further back than this we cannot go, the Geological record as regards insects is extremely fragmentary and discontinuous, and we really have not the slightest evidence as to when, where, or how the differentiation of existing specific forms among the Coleoptera, or indeed of any other order of insects, took place.

But we are not now considering the origin of insects, but their distribution in Britain and immediate derivation, and we cannot get far into the subject before we discover that any theories we may form on the matter will depend ultimately on the view we take of that vast secular catastrophe known as the Glacial Age.

How intense was that cold? Did an ice sheet cover the whole of the British Islands as to-day it does Greenland? Can we regard the almost entire submergence of this country during or at the close of the glacial epoch as incontrovertible? In short, were the climatic and other conditions such that the whole of the preceding Tertiary fauna of Great Britain must have been extirpated and destroyed? Was such a clean sweep made of the whole of antecedent life that when the great refrigeration passed, or when the land stood once more above the waters, there was presented a *tabula rasa*, and an empty stage on which the actors in our present drama of life might appear for the first time?

These are the questions which, at the outset of our enquiry, confront us, questions you will observe so very much more easily asked than answered. For it appears that opinion on these points is not quite uniform, and, indeed, seems recently to have become, as regards the severity of this refrigeration, somewhat modified.

Many great authorities, however, hold extreme views. Thus, Dr. Wallace says—"The submergence destroyed

this (ante-glacial fauna) or at least the greater part of it.”*

Prof. J. Geikie remarks—“As neither our animals nor our plants could have existed in the British Islands during the last glacial epoch, it follows that they must be of post-glacial age;† and another Geologist, Mr. Clement Reed, says—“In the Britain of the present day we may study the repeopling of a country over which everything had been exterminated.”‡

On the other hand, Dr. Scharff, of Dublin, has lately written a very interesting monograph on this subject, the burden of which is to demonstrate the probability of the uninterrupted continuity of the British Fauna since pre-glacial times. For so revolutionary a view, however, the evidence seems inadequate. The climatic conditions which we know from data quite other than faunistic must have prevailed, still more such a submergence as the shell-beds of Tryfan and Macclesfield might suggest, could not but have very considerably modified the previous fauna and flora, if it did not exterminate them. A remnant may have escaped the cold by a southern migration, and an archipelago of islets may have afforded a refuge from a submergence; but I doubt whether, in any case, it can be safely maintained that our present flora and fauna are merely an uninterrupted continuation of those of late Tertiary days.

However, leaving ground so debatable, let us turn to the animals themselves, and see what light they throw on the subject.

In the first place, we must exclude from consideration any species which owes its appearance here to other than purely natural agencies. There are probably very few

* “Island Life,” p. 338. † “Gr. Ice Age,” 3rd ed., 1894.

‡ “Flora of Greenland.”

such introductions in the British Fauna, and more in the flora than the fauna of most islands. By non-natural, I mean introductions which are in any way directly or indirectly due to the appearance of humanity on the scene. Cases of the sort, of course, do occur, and impress one by the rapidity of their advance. There is, for instance, the oak-gall fly, *Cynips kollari*, which produces our familiar oak apple, and this insect appears to have been first introduced into Devonshire and restricted to that county not much more than half a century ago—now every oak tree in the country testifies to the extent of its present range. The deplorable ubiquity of the common cockroach is another case in point among the insecta.

On the other hand, among mammals we have the poor success which has attended all attempts to introduce our common English hare into Ireland, whose native form is a closely allied but distinct species the Arctic or mountain hare. Here some unknown influence seems to resist the establishment of a new species in an area which appears to be perfectly suitable to its maintainence. Generally speaking the adjustment between existing species and their environment in any region is so close and so exact that there is no room, not the least chink of an interstice, into which a new arrival can thrust itself, and the nearer genetically such a would-be immigrant may be to forms already existing, so much the more difficult is its entrance made.

Where we *do* find such introductions is where the environment itself has been changed by man, and among the Coleoptera there are perhaps 40 or 50 species, quasi-domesticated, the Beetles of granaries and bakeries and grocers shops. These we must eliminate in any consideration of the natural distribution of the group.

But, considering the matter a little further, we discover,

from a very brief study of the physiological characteristics of the Coleoptera, as of any other order of insects, that the species themselves clearly fall into two groups, which we may call the adaptables and the non-adaptables, or, if we like, the progressives and the conservatives—that is, species which are common everywhere, and species which are either generally rare or common only locally; in other words, there are a certain number of forms which have successfully solved the problem of the continual adjustment of themselves to an ever-changing environment, and those who, failing to do so, perish when their own particular environment ceases to be. These latter certainly form the bulk of the species. There are Beetles attached to the sandy wastes of the shore, to marshes, forests, heaths, mosses; and when you turn your sandhills into docks and golf links, drain your mosses and bogs, cut down your woodlands and cultivate your desert wildernesses, then the non-adaptable, the conservatives of the feral population of such places, pass to return no more; they are incapable of the necessary new adaptations. Hence it is that inasmuch as the physical characteristics of this country are continually changing, and that at an increasing ratio, the extinction of most of our conservative species of animals is merely a matter of time. This process has almost completed itself among the mammals, is in full swing among the birds, and is quite noticeable among such an insect group as the Diurnal Lepidoptera. It must, however, be admitted that there is no evidence of any extinction of specific forms among the Coleoptera as yet, and I have, perhaps, rather exceeded the strict lines of my subject on this point, because I want to impress the distinction between such species, which are the only ones that are of any service to us, in our endeavour to discover the derivation of any of them—between these and those

other progressive species who have established a sort of *modus vivendi* with civilization, readily adapt themselves to those altered conditions which agriculture, among other agencies, has imposed, and thrive under a new regime. Such species we call common, and most of the others rare, but the mystery of *why* one species of a genus can so adapt itself, and another, so far as we can see, similar physiologically, refuses to do so, is as impenetrable as ever; and to say that the fittest always survive only restates the fact in other words, and does not explain it.

However, the point is that those species which *have* become fit, and are therefore common everywhere, are not the slightest guide to us in our search for the causes and methods of original distribution. Their facility for adaptation is so great, that whether they may have arrived early or late, from the north, south, east, or west, it comes to quite the same thing, that is, their present ubiquity and the complete obliteration of all their past proceedings.

We must thus eliminate at the commencement of our enquiry all such quasi-domesticated Beetles as those of the genera *Dermestes*, *Pellio*, *Anthrenus*, or *Alphitobius*, and all such ubiquitous species as *Nebria brevicollis*, or *Harpalus aeneus*, which appear to be equally abundant from Cornwall to Caithness, and from the top of Ben Nevis to below high-water mark.

These exceptions, however, will be found to be but trifling, and when we study the distribution of the great bulk of our Coleopterous Fauna which will remain, we shall, I think, discover that they can be, with more or less precision, arranged in at least three groups, or rather, that in their grouping we discover at least three diverse elements, and this diversion will be quite independent of genetic affinities; in fact, we shall be able to find in any of the larger genera members belonging to each of them.

We have, firstly, a somewhat small group of species occurring in regions of the north and north-west, elsewhere inhabiting only mountains and elevated moorlands. This group has been called the Arctic, the Glacial, or the Celtic Fauna, all terms which, to some extent, beg the question at issue. Perhaps the Celtic is the better term, if we can eliminate the idea that the group is necessarily comparable with the Celtic race, ethnologically considered. Its range is principally in Scotland and western Ireland. Several species occur there which do *not* occur in England, but no single species occurs in England which does not *also* occur in Scotland or Ireland, or both. Next we have a group which contains by far the greater proportion of our species. They have been called the *Siberian* immigration; whether their ultimate starting point was Siberia or not, it is clear that their proximate origin was the plain of Central Europe, that they arrived here from the south-east and east, and that during their dispersal throughout this country some obstacle, though probably not entire separation, prevented complete access into Ireland. These are species generally but by no means equally distributed over Great Britain, not restricted to elevation, but often rigidly so by other conditions of environment; from a maximum density in the south and east, they thin out northward and westward, till many of their forms are rare in Scotland and some altogether wanting in Ireland.

The third group is perhaps more difficult to define, and its members cannot always be disentangled from those of the second group. We should comprise in it all those species whose distribution is exclusively southern or south-western, and is often marked by extreme discontinuity. This is known as the Teutonic element in its eastern and the Iberian in its western extension. The former, the south coast of England, the latter, the south and south-

west of Ireland. The characteristics of this fauna are very enigmatical; some species occur only in England, some few only in Ireland, and some are common to both. From Scotland the group is quite absent.

Now, from what is now known of the distribution of the British Coleoptera, we could go through the entire list and allocate, with more or less precision, nearly every species to one or other of these groups. And the questions suggested by so doing would be something like these—Do such groups really represent separate waves or streams of immigration? Are they of different age, and if so, in what relation as regards time do they stand to one another? Did separate areas originate them, or only separate epochs?

Now, to answer, as some have done, firstly, that all life was destroyed over these islands either by the severity of glacial conditions or by submergence, and secondly, that during the slow subsequent amelioration of the climate these streams of migration arrived in the order in which I have mentioned them, and that sometime during this process, but subsequent to the dispersal of the first group, the connection between Great Britain and Ireland broke down, may appear a simple explanation, but however well it may fit some of the fauna or flora, certainly it does not exhaustively explain *all* the facts of their distribution. It does not explain the vestiges of a distinctively Iberian fauna, still less those of a North American one in Ireland.

To make this clearer, let us consider these groups a little more in detail. Our first or Celtic division's maximum development is in the north, from Orkney and Shetland, over all the Highlands and all the western isles of Scotland, and all the mountains north and west of Ireland

down to Kerry. It is only partially represented in the Welsh mountains, and some of its species occur sporadically in England. In Europe all the species occur in Scandinavia, many of them on the Alps. Take two of them—that large water Beetle, *Dytiscus lapponicus*, and a smaller ground Beetle, *Pelophila borealis*. Both occur in the extreme west of Scotland and Ireland, where they are abundant, but neither in England, although in Cumberland, Yorkshire, or Wales the environment would be perfectly appropriate to them. Now, it is difficult to understand, if these two species formed part of the earliest immigration from the *south-east* or *east*, why they should be both absent from an area over which they must have travelled to arrive at their present home.

Other species, such as *Carabus glabratus* and *Miscodera arctica* do occur at suitable elevations in the north of England and in Wales, while one species, *Carabus clathratus*, with a general range almost as limited as *Dytiscus lapponicus*, has been recorded from Suffolk, but there is no example of a high mountain or moorland species which attains a maximum in England or Wales, and thence thins out north or west, such as one might have expected had the original entrance of such species been from the south or east at however remote a date.

Leaving the Coleoptera however for a moment, but still considering the Irish fauna, we cannot but be struck by the remarkable occurrence of three species of North American fresh-water sponges in the south and west of Ireland, species not occurring elsewhere in Europe. These were discovered by Dr. Hanitsch—a well-known former member of this Society—about four years ago.

Dr. Hanitsch himself suggests that their presence might be due to the gemmules of these sponges having been carried attached to the feet of birds across the Atlantic.

They may also afford evidence of a former land connection which, closing in the Atlantic on the North, united Ireland, Scotland, Norway, Iceland, and Greenland. Such a continental land extension might well have been the home of what we call the Celtic element in our western fauna, as well as the bridge which carried those American species which we recognize both in the Irish flora as well as fauna. Thence any immigration would have been from the north-west, south and eastwards, which is what the facts of our Coleopterous distribution of this group require. The difficulty comes in when we attempt to harmonize this theory with preconceived notions of the severity of glacial times, for, of course, if that severity were such as to forbid the existence of animal life in Great Britain, still more would it be impossible in this hypothetical northern land, and any migration would necessarily have had to proceed from the south northwards. If, however, we may be allowed to suppose that the British glacial climate after all might have permitted the continued existence of this Celtic fauna, then we see no difficulty in conceiving that fauna, as originally a pre-glacial one inhabiting a region to the north-west, now lost and driven southward by the advent of glacial conditions which certainly would have made such a northern land untenable, instead of led up northwards from the south on the cessation of such conditions. In any case, I think we may look upon the species comprised in this first group as distinctly older residents than the vast mass of species whose advent was more indubitably from the south and east, and perhaps this is as much as one can safely say.

Proceeding, then, to a consideration of our second group, we see no reason to doubt that their advent was from the east and south-east at a time when the German Ocean was dry land. The distribution of some of them is

still very limited; thus, I should assign to this group such an insect as *Nebria livida*, whose occurrence is restricted to the sea coast of Yorkshire, and most of the fen species. Many of them are phytophagous and attached to special plants; others, creophagous or necrophagous, and so dependent on the existence of higher animals. These factors rather complicate the question, as it becomes evident that the distribution of the Beetles is limited by the possibilities of distribution of their various hosts and food plants. I have already remarked that a proportion of this group does not seem to have reached Ireland at all. It is quite true that up to within about ten years ago very little was known of the Coleoptera of Ireland, and that, since that time, every year has added species to the Irish list, but as the Irish deficiency in mammals, and still more in reptilia, is certain and notorious, it is perhaps a fair presumption that many of these Coleoptera do not really exist there. In this connection I should like to point out that the Manx Coleopterous fauna, so far as it has been studied, is quite Irish in character; even that peculiarly Irish form *Silpha subrotundata* occurs there. It exhibits the same preponderance of the Celtic group, the same differences in the eastern one, and, curiously enough, a quite southern English species, the well-known rose chafer, *Cetonia aurata*, which has rather surprised entomologists by having been recently found in Arran Island, off Galway and in the extreme west of Kerry, Clare, and Donegal; has also occurred in the Isle of Man. So little, however, is really known of the Manx Coleoptera, that it would be rash to hazard any theories on the meagre facts in our possession.

We may, I think, take it for granted that no species now, except under exceptional and non-natural conditions, is increasing or ever will increase its range. No doubt

freedom from competition, either directly or indirectly through food plants, &c., in certain suitable areas first fixed the lines of migration and settlement. As however, the available land surface became more and more crowded, fixity of tenure would become more and more the order of things, so that it seems probable that there must have been a point somewhere in the past which marked the final equilibrium of the forces of dispersal and the stress of competition, and that since this point was reached, most movement has been in the form of retrogression and due to human interference with environment.

We can thus understand that, given an original exotic immigration of an assemblage of species from the east (firstly), the rate of progress, initially perhaps high, would be continually decreasing till it came to a dead stop, and that no length of time elapsing since then would renew it except by organic change in the species themselves through natural selection, and that (secondly) the rate of advance among the species themselves would be very unequal. In Nature the race is always to the swift, the battle invariably to the strong. This explains why some species arrived in Ireland while others were too late, and so cut off, or, what is more probable, since there are similar deficiencies in the Scotch Fauna, that their rate of progress was so slow, that before they had got half this distance, progress at all became impossible.

The characteristics of this second or Central European group, then, are that from a maximum in the east and south-east it thins out both specifically and individually westward and northward, and if we find a species, as we do several, whose maximum seems to be in Kerry, Cornwall, and South Wales, but is absent or rare in Norfolk, Essex, and Kent, then we may, I think, assign such a species *ipso facto* to our third group.

To a consideration of this assemblage we will therefore now proceed, and it undoubtedly exhibits perhaps the most puzzling features of them all. I should include in this group, firstly, all species whose northward range does not pass beyond the Thames Valley and the Bristol Channel, and secondly, a certain number of Southern European forms found in Ireland, but not to the same extent in England. There can be no doubt but that this element in our fauna is distinctly southern, or relative to Europe as a whole south-western. There seems to have been two lines of migration, one, which crossing the English Channel from directly south, does not appear to have extended further westward than Devonshire, another which seems to have had an origin in some much more western ancient land extension, spread itself through Ireland in a curiously disconnected manner, and left vestiges of its migration in Cornwall and Devonshire.

Calling this then the southern group, we find:—

Firstly, species such as *Lucanus Cervus*, *Cicindela germanica*, or *Carabus intricatus* among the Beetles. Among other insects, the Giant Earwig, only known to inhabit a few isolated spots along the Sussex and Hampshire coast, or the butterfly called the Lulworth Skipper, found only at Lulworth, in Dorset. These are species which do not extend northward of the Thames Valley, are very rare or absent west of Dorset, and quite absent from any part of Ireland.

Secondly, species common to the south and west of Ireland and England, but principally the extreme west of England; such are *Mesites Tardyi* and *Chrysomela Banksii*. Some of these exhibit discontinuity of range to so high a degree as almost to suggest two separate streams of migration. Thus *Pyropterus affinis*, a brilliant scarlet Beetle and one not likely to be overlooked by collectors, has so far been

taken only in Sherwood Forest and Killarney. That brilliant insect, too, *Lytta vesicatoria*, until, to the amazement of coleopterists, it turned up last year in Roscommon, might have been regarded as a peculiarly English species, as it had only been taken a few times in Kent and Hampshire. Another conspicuous Beetle, *Nebria complanata*, in England, inhabits only the sandy shores of the Bristol Channel, and, in Ireland, a short strip of the Wexford coast immediately opposite. This case however, I consider it allowable to hold to be due to accidental transference, since the species is purely littoral in its habits and is fond of hiding under and in the crevices of drift wood lying on the shore. Hence its transport across from the Bristol Channel to Wexford is not inconceivable.

And thirdly, we have species which are *only* found in Ireland; this has been called the Iberian element in the fauna of that enigmatical island and the spotted slug of Kerry. *Geomalacus maculosus* is a famous example of it. It is, I believe, also well marked in the flora. There is a house spider, *Tegenaria hibernica*, the special pride of Dublin, and a jumping spider, *Attus floricola*, from Lough Corrib, discovered only two years ago, both unknown elsewhere in the British Islands. Among the Coleoptera, so far, we can name only *Silpha subrotundata* and *Otiorrhynchus auropunctatus*; and, curiously enough, this latter species has more an eastern than a western range; but when the wilds of Kerry and Clare have been more thoroughly explored by Coleopterists, I doubt not that the list will be larger one.

Now, these facts require a great deal of explanation, the more so if we grant any community of origin to the species under discussion, for some of them exhibit great discontinuity of distribution which, according to Dr. Wallace and other high authorities, infers great antiquity of origin,

and others an equal but limited homogeneity, which seems to imply a recent arrival.

I think we must admit from their generally southern range that they are all post-glacial, and it might also be a plausible conjecture that the Iberian element, that is, the Irish or Irish and West Anglian species were earlier than the South Anglian. It seems also probable that while it is certain Ireland must have been joined with an extreme western extension of Europe during the advent of the former, that country may have been quite insulated while the advent of the latter took place across what is now the eastern part of the English Channel. Moreover, there seem to be grounds for assuming that at a time when Cornwall, Kerry, France, and Portugal were all united, some obstacle, such as an immense lake, existed where the Irish Sea and St. George's Channel are now. This would explain the phenomenon of bifurcation in the lines of distribution of such a species as *Cetonia aurata*, which does not extend much beyond the midlands in England, while it goes right up to Donegal in Ireland, and also occurs in Man; or of *Pyropterus affinis*, which, as I have mentioned before, occurs in Kerry in Ireland and Nottinghamshire in England.

Further than such problematical conjectures, or, at best, working hypotheses, I doubt if we are justified in going for the subject is a very difficult one, and in my own opinion hardly at present ripe for discussion. We have after all not a very complete basis of facts to go upon, there may have been many streams, and many periods of migration from the same region, and I doubt whether it is possible, perhaps ever will be possible, to quite disentangle these threads, or to prove the exact limit as regards species of northern, eastern, or southern derivation.

Indeed, none of these various schemes, conjectures, and hypotheses will stand working out in complete detail. All we can hope to do, at any rate at present, is to get hold of some few general principals, and to test those by all the evidence at our command, and by application to the whole of both fauna and flora.

Some such principles I hope emerge from the fog of conjecture through which we have been travelling. As that we can certainly detect a threefold, if not a fourfold, disparity in our insect fauna; that its phenomena point, at any rate, to past land extensions to the north-west and to the south-west, now entirely swept away; that Ireland must have been separated from the greater part of England by an obstacle of some kind while the fauna was in process of establishment, and while or after it was itself continuous with an extension of Western Europe, and that it is not impossible that some extreme estimate of the severity of the glacial climate may require modification. Furthermore, that if any of our Coleoptera can be termed autochthonous, the northern or Celtic element is the only one that can be so regarded, and that, while all the rest of the fauna seems to have been derived from the south and east, this only may have had a northern origin and be possibly pre-glacial. These are conclusions which we may perhaps entertain as provisional hypothesis. For the rest, perhaps all I have succeeded in making plain is how vastly our ignorance exceeds our knowledge of the factors of the problem; and this is especially the case with a group of insects such as we have been considering. For mark the difficulties of the quest. Insects, although, because they are probably much older as distinct species, and also because both specifically and individually they are very much more numerous than the higher vertebrata, furnish more abundant evidence of faunistic distribution,

yet because of their minute size and curiously spasmodic appearances and disappearances make the investigation of their occurrences, and more especially of their non-occurrences, all the more difficult.

For instance, whether or no the beaver is now extinct in the British Islands, there can hardly be too opinions. Scarcely the most persistent optimist can cherish the hope that the great copper butterfly will ever again be seen of mortal eyes in the eastern fens; but what amount of negative evidence is sufficient to justify the assumption that such and such a species of *Homalota* or *Atonaria* does *not* occur in any particular locality. A single properly verified record is sufficient to establish the positive side, but as the proof of the negative is proverbially a hard matter, so in a case where the subjects are so minute and so elusive, it verges on the impossible.

Furthermore, there is an even still more perplexing factor in the problem, and that is what I have just alluded to as the spasmodic method of appearance of so many insects. This is a very interesting subject, and very worthy of more attention and investigation than it has yet received. The extraordinary irregularity of such an insect as the hawk moth, *Deilephila galii*, is a case in point, but the characteristic prevails more or less among all insect life.

Doubtless the meaning of such phenomena is to be found in the singular delicacy of adjustment between insects and their environment, so that the most minute and obscure change in the latter is responded to in a greatly enhanced and apparently exaggerated degree by the former, although the connection may be quite unknown to us, and often indirect.

But I firmly believe that a large proportion of what is

generally regarded as discontinuity of *occurrence* should be more correctly attributed to discontinuity of *appearance*.

Consider, for instance, such a case as *Aegialia rufa*, a small Lamellicorn Beetle supposed to be peculiar to the littoral of Lancashire and Cheshire in this country. Now, within say the last thirty years, this district, that is, the coast sandhills from Southport to Crosby and from Wallasey to Hoylake has been, perhaps, as well searched year by year by entomologists as any other of equal extent in the kingdom, and this perplexing insect has during three or four summers of this period appeared in profusion. On those occasions it has, of course, been discovered and recorded for this district only. This, on the face of it, supplies an amazing instance of discontinuity of distribution; but if the sandhills all round the coast had been as persistently searched as those of Lancashire and Cheshire, is it unimaginable that *Aegialia rufa* might, in its years of plenty, have been taken in many other localities; in fact, wherever round these coasts a suitable habitat offered itself? You observe that, in this case, the Coleopterist might have searched the Crosby and Wallasey sandhills seven or eight years in succession, and declared as the result of his investigation that *Aegialia rufa* did not occur in that district. Another observer goes there the next season and finds the insect one of the most abundant of the fauna.

You will gather from this that the study of the distribution of our insect fauna is beset with peculiar difficulties, and that only close and systematic observation, extending over a long course of years, is sufficient to justify the assumption of the non-occurrence of many species in any particular locality. This is just what we have not got. I doubt if there be fifty Coleopterists in the whole of the British Islands who systematically record the occurrences

of the order which they study. It is true we have a sufficient mass of evidence to enable us to form broad generalities, such as I have indicated in this paper; but until that evidence is more copious and more complete, it is obvious that they cannot be much more than provisional, and it is certain that at present the aim of all students of this—and, indeed, all orders of insects—should be more the accumulation of facts than the exploitation of theories.

I will therefore conclude these somewhat unsatisfactory and disjointed observations by expressing the belief that among the various functions of the many local natural science and biological societies now in existence among us, none excel in importance the accurate and systematic verification and record of the flora and fauna of their own particular district. As I have already said, many of the feral inhabitants of these islands are swiftly passing; many to a future generation of investigators will be but empty names, and as they disappear, leaving no trace of their sojourn here, they reduce little by little the possible evidence by which we may ever hope to understand the problems of their past migrations and distribution. Much evidence of this kind is undoubtedly beyond recall, but it is obvious to any one who has at all studied the distribution of our Insecta, that had we, instead of the disconnected and often overlapping lists of records of individual students and collectors, the authoritative table of corporate bodies of workers, formed on some comprehensive system, carefully verified, and recorded in some permanent and progressive method, we should be enabled far more hopefully to face the task of the elucidation of such a tangled web as has formed the subject of our attention this evening.

On SECONDARY THICKENING in the AERIAL ROOTS of HEDERA HELIX.

BY

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Professor of Botany in University College, Liverpool.

With Plate III.

[Read January 13th, 1899.]

I RECEIVED lately, through the kindness of Miss May Rathbone of Neston, Cheshire, a portion of an ivy plant whose aerial roots appeared to have undergone a somewhat curious change. Instead of showing the usual small aerial roots of from half-an-inch to an inch in length, the branch was provided with roots 6 or 8 inches long, profusely branched and considerably swollen especially for the last 2 inches of their length.

The plant had been grown in a large pot in a room and trained up the side of the window, and from about a foot above the pot up to the topmost branches which twined round the curtain rod exhibited both normal and abnormal roots. They developed from the stems at all angles, quite irrespective of light, and often all round the stem.

The normal aerial root of ivy shows, as has been described and figured by Van Tieghem (*L'origine des membres endogènes*, 1889) and others, a central vascular cylinder surrounded by a well marked endodermis (*d*) fig. 1. There are, as a rule, five protoxylems (*h*) united centrally by a strongly sclerotic medullary region (*g*). The pericycle (*e*) is, as a rule, from one to two layers thick between the phloem and the endodermis, but may be three layered opposite the protoxylems.

The phloem (*f*) is small celled and not markedly distinct from the pericycle.

The endodermis is followed by a fairly thick cortex (*c*) limited by a piliferous layer (*a*) replaced later by an exodermis (*b*).

On examining the swollen roots one finds the number of protoxylems greatly increased. A section of such a root as that shown at figs. 2 or 3 may show from 12 to 20 protoxylems united by a sclerotic medulla.

The protoxylems stand out prominently, creating deep bays in which the phloem lies (fig. 4).

The pericycle is, in the swollen roots, much thicker, averaging 4—5 cells in depth.

The endodermis is again well marked and is followed by a thick cortex.

As the root becomes older two cambiums make their appearance in a manner quite similar to that seen in a normal terrestrial dicotyledonous root.

The first beginning of the change is apparently the development of a phellogen from the most external layer of the pericycle. Tangential division in this layer results in the formation of a distinct layer of phellem and is followed by the shrivelling of the original cortex and rupture and disintegration of it as well as of the endodermis. At the same time, or more commonly somewhat later, a cambium appears inside the phloem at the base of each concavity formed by the prominent protoxylems, becoming gradually completed from the pericycle outside the protoxylems. Secondary thickening, chiefly of xylem, is now added in the ordinary way until the bays become filled up with secondary xylem (figs. 5 and 6).

In the flattened roots (fig. 7) as many as 50 protoxylems or even more (fig. 8) may occur.

Similar instances of secondary thickening in aerial roots are known to occur in certain Melastomaceæ, but I am not aware that the phenomenon has been previously observed in *Hedera*; at all events I have been unable to find any reference to the subject in the literature.

EXPLANATION OF PLATE.

- Fig. 1. Transverse section of normal aerial root of *Hedera helix*.
Figs. 2, 3 and 7. Abnormal roots of *Hedera*.
Fig. 4. Transverse section of abnormal root, showing a large number of prominent protoxylems.
Fig. 5 and 6. Development of phellogen and cambium in abnormal roots.
Fig. 8. Transverse section of abnormal root with 50 protoxylems.

ADDENDUM to REPORT on a small COLLECTION
of ANTARCTIC PLANKTON,* &c.

SINCE the publication of the paper with above title in last year's L. B. S. Trans., I have received a communication from Mr. William S. Bruce, F.R.S.G.S., who it appears was along with Dr. Charles W. Donald, the collector of the Plankton handed to me by Prof. D'Arcy Thompson, C.B. Mr. Bruce points out to me that it was due almost entirely to the generosity of Mr. B. Leigh Smith (of Franz Josef Land fame), who contributed nearly £100 towards the Biological outfit, that the collection was made. Prof. D'Arcy Thompson also presented a few bottles and some spirit to Dr. Donald. Mr. Bruce and Dr. Donald were chosen by the Royal Geographical Society, and Mr. Leigh Smith, to undertake the naturalist's work, on board the two whalers "Balaena" and "Active," which work they voluntarily undertook.

On their return to Scotland in 1893 they presented their collections, with the approval of Mr. Leigh Smith, to the Museum of University College, Dundee, under the care of Prof. D'Arcy Thompson, who forwarded the Plankton to me for identification. It is regretable that I have been unable to obtain certain notes on the collection, which Mr. Bruce tells me both Dr. Donald and he handed to Prof. D'Arcy Thompson on their return from the Antarctic.

It appears that the collectors worked under very considerable difficulties and in great discomfort on board their vessels, greater even than might have been expected

*Trans. L'pool Biol. Soc., vol. XII., p. 291.

on board a whaler. Hence the smallness of the collections. Mr. Bruce mentions that the time they were actually in the ice was from December 12th, 1892, to February 26th, 1893.

Referring to the mysterious presence of several fresh-water animals in one of the bottles sent to me labelled "Antarctic," Mr. Bruce thinks it probable that the bottle in question was part of his Falkland Island fresh-water collection. He also explains the occurrence of a number of tropical species of Copepoda in another bottle (*loc. cit.* p. 296) by the fact that they were collected by tow-net in latitude $4^{\circ} 02' N.$, longitude $23^{\circ} 02' W.$, as the missing notes, supplied to the Dundee Museum with the collection, showed.

ISAAC C. THOMPSON.

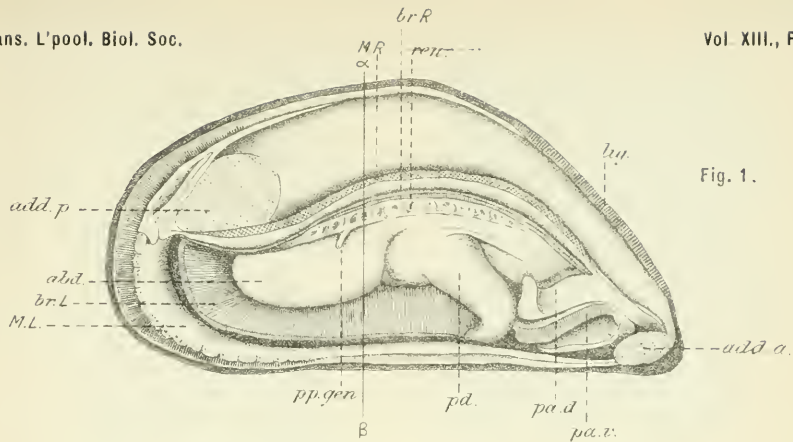


Fig. 1.

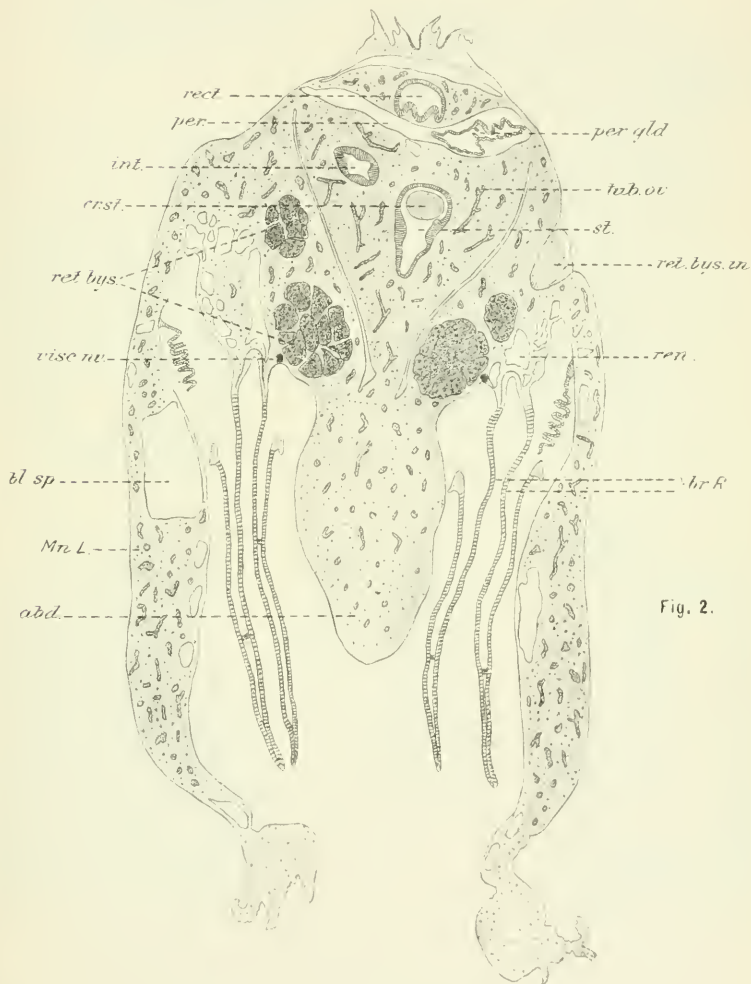


Fig. 2.

Fig. 1.



Fig. 2.

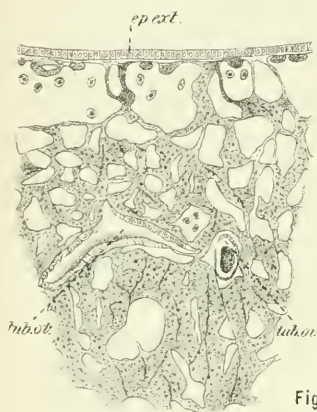
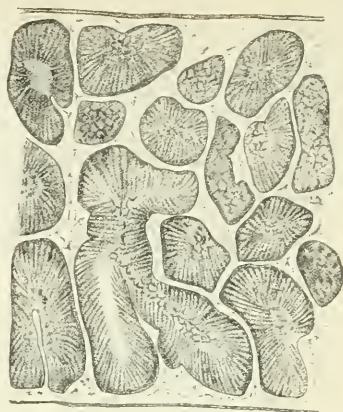


Fig. 3.

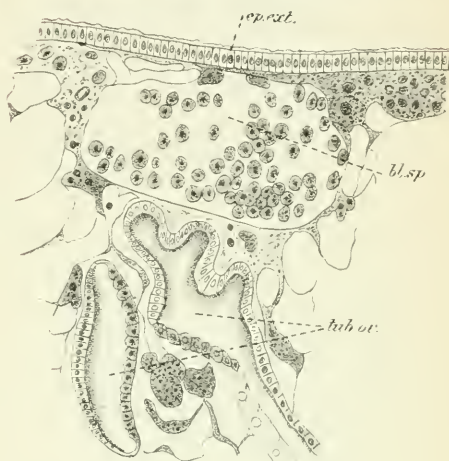


Fig. 4.



Fig. 5.



Fig. 6.

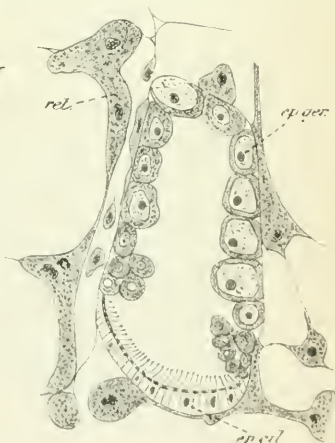


Fig. 7.

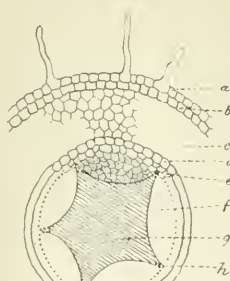


Fig. 1.

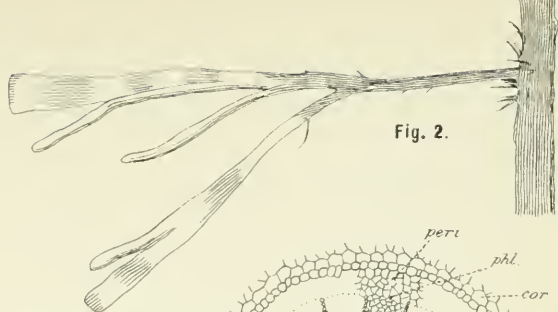


Fig. 2.

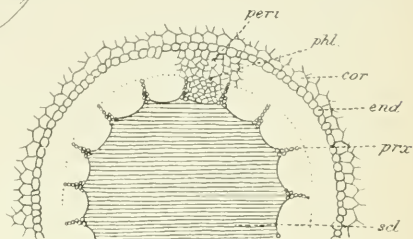


Fig. 4.

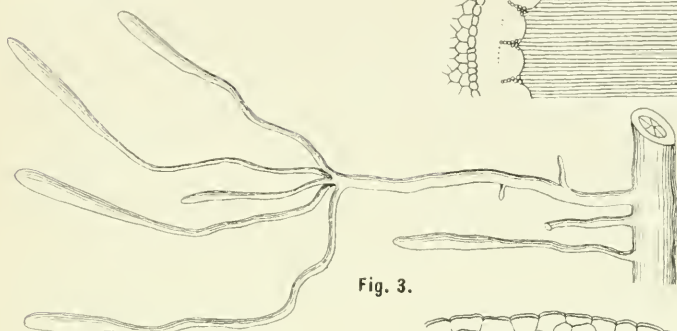


Fig. 3.

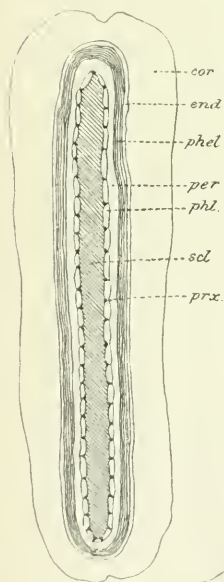


Fig. 8.

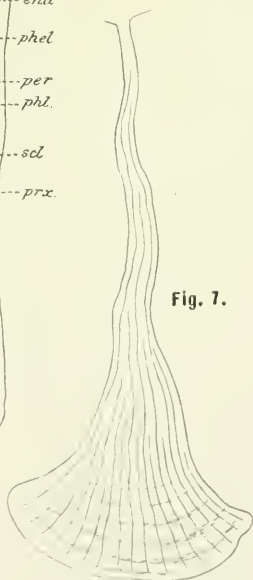


Fig. 7.

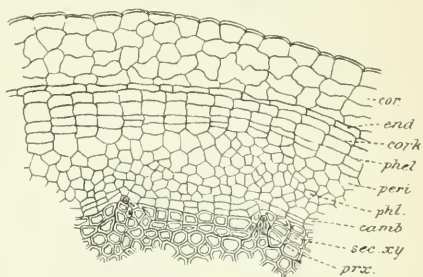


Fig. 6.

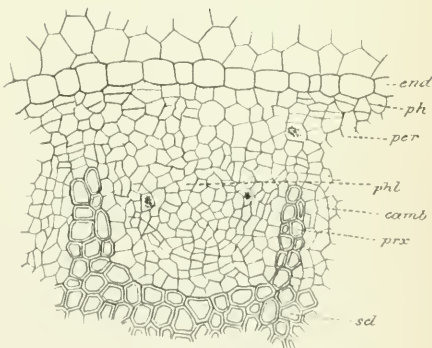


Fig. 5.

